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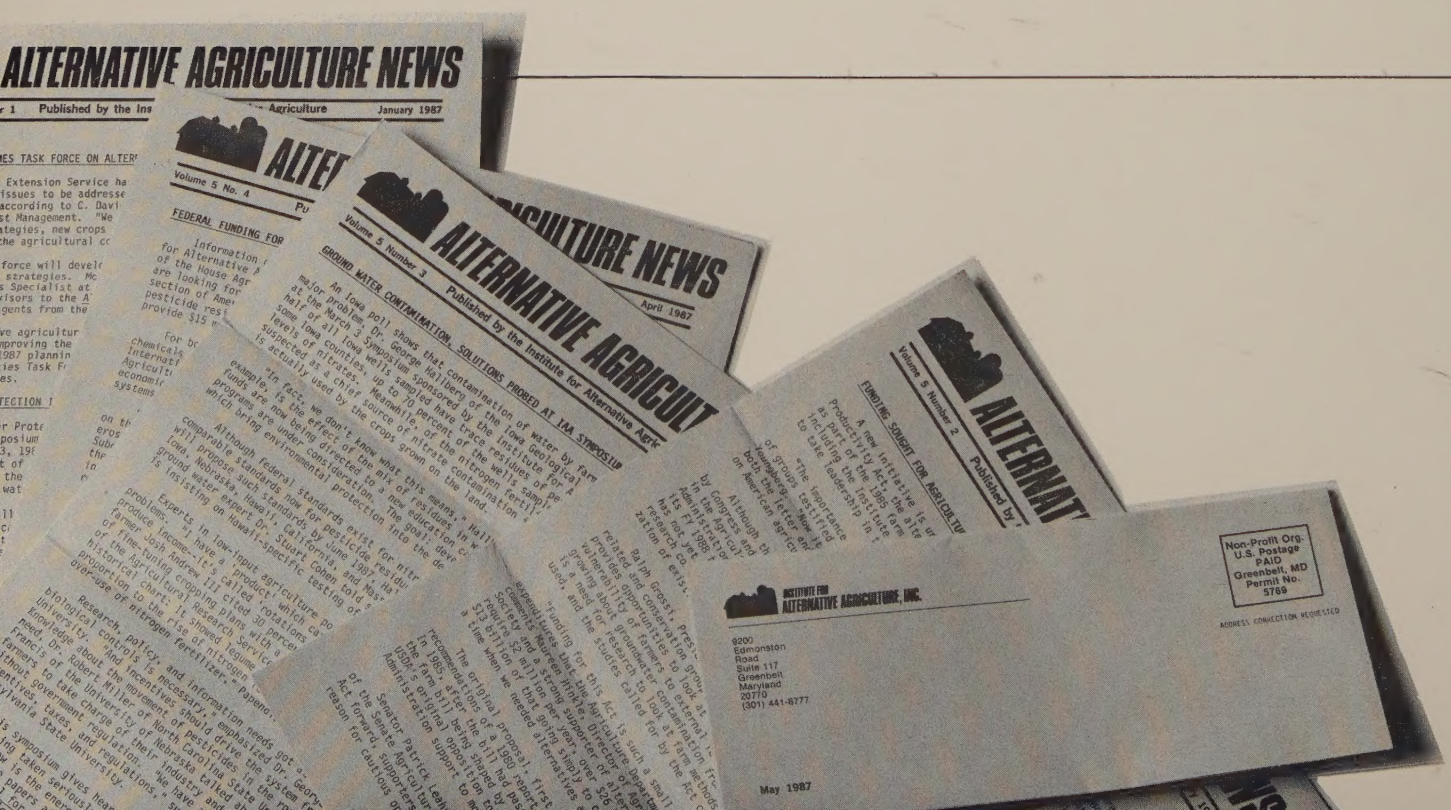

AMERICAN JOURNAL OF
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Volume 5, Number 2

TABLE OF CONTENTS

Articles

51 Alley cropping as a sustainable agricultural technology for the hillsides of Haiti: Experience of an agroforestry outreach project
Michael E. Bannister and P.K.R. Nair

60 Farming with reduced synthetic chemicals in North Carolina
Molly Anderson

69 Energy, water, and economic savings of improved production systems on the Texas High Plains
Sharif M. Masud and Ronald D. Lacewell

76 Policies, programs, and regulations to support the transition to sustainable agriculture in Canada
Rod J. MacRae, Stuart B. Hill, John Henning, and Alison J. Bentley

Departments

From the Editor—50 • Opinion—50 • Resources—59 • Book Reviews—93 • Upcoming Events—94 • Institute News—95

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Institute Information

The Institute for Alternative Agriculture is a nonprofit, tax-exempt research and education organization established in 1983 to encourage and facilitate the adoption of low-cost, resource-conserving and environmentally-sound farming methods. It works closely with producer groups, public research and education institutions, and government agencies in promoting a sustainable agriculture system.

Its programs include providing a national information clearinghouse, serving as a voice for sustainable agriculture in Washington, and developing and implementing research and educational outreach programs. It holds an annual scientific symposium and publishes a monthly newsletter.

The Institute is governed by a grass roots Board of Directors, which includes several commercial-scale organic farmers, and maintains a small professional staff. It is supported by memberships and donations and grants from foundations, corporations, and individuals.

Cover Photo

The photograph from a farmer's field in Haiti shows an agroforestry practice of growing greater yam (*Dioscorea alata*), an edible tuber crop, by trailing it on to *Leucaena leucocephala*, a nitrogen-fixing tropical tree legume, which can be pruned repeatedly for its nitrogen-rich foliage that can be used as an excellent animal fodder or as a green manure to provide nutrients to the accompanying crops. Photo by Dr. P.K.R. Nair, Department of Forestry, University of Florida, Gainesville, FL.

FROM THE EDITOR

Robert Rodale: A remembrance and perspective

In late September, Robert Rodale, Chairman and CEO of Rodale Press in Emmaus, Pennsylvania, was killed at age 60 in a Moscow car accident. He was in the Soviet Union working on publication of a Russian language version of *The New Farm*. As always, Bob was attempting to reach still another audience with his message of agricultural and community regeneration.

Speaking out on the importance of what Bob called regenerative agriculture was a central and abiding aspect of his life. In the fullness of time, history no doubt will provide a more complete picture of Bob's influence on agriculture and health policy, both here and abroad. For now, in the immediate aftermath of this tragic loss, it is only possible to offer a personal and tentative sketch.

I first met Bob Rodale in 1979 during the initial phases of work on USDA's 1980 organic farming report. I well remember his interest in my earlier work on the ideology of alternative agriculture. We discussed this matter several times during a 10-day tour of organic farms in Europe in the Fall of 1979.

During his active life, Bob must have touched scores of others in a similarly personal and positive way. This alone is a major contribution. However, it seems quite likely that Bob will be remembered most, at least within agricultural circles, for his impact on our agricultural thought and institutions.

Over the past 10 years or so, under Bob's guidance, agricultural activities at Rodale Press focused increasingly on the science of alternative production systems. The hiring of Richard Harwood in 1978 as Director of Research, coupled with creation of the Rodale Institute, the nonprofit arm of Rodale Press, in 1982, marked a major turning point in Bob's efforts to bring scientific credibility to the field. These efforts continue. Through Rodale International, a division of the Rodale Institute, they now extend worldwide. Such publications as *The New Farm* and *Organic Gardening* carry information to an enormous lay and professional audience.

In the mid 1980's, Bob's attention began to focus on the research and education policy needs of alternative agriculture. The Rodale organization was one of the many groups instrumental in developing USDA's LISA program.

Bob Rodale was a major ideological and spiritual figure within alternative agricultural circles. During more recent years, his influence extended to the conventional agricultural community as well. His untimely death constitutes a profound loss for all of agriculture. We hope that his personal legacy, including the role of the Rodale organization, will continue under new leadership. To those faced with the daunting task of guiding the Rodale organization in the years ahead, we offer our hand of cooperation. To Bob's family, close friends, and colleagues, we offer our sincere sympathy.

Garth Youngberg, Editor

OPINION

Developing a socially sustainable agriculture

Chuck Hassebrook

Sustainable agricultural systems should be shaped to enhance the quality of the social as well as the natural environment. Toward that end, we should develop environmentally sound farming systems that maximize the number of economic opportunities for people to own and operate their own farms and that reduce socioeconomic inequality.

This idea runs counter to much of the conventional wisdom in both agricultural and environmental circles, which shuns socioeconomic structure concerns and resists mixing social with environmental issues. However, research has revealed an inextricable link between the structure of agriculture and the quality of life in rural communities--in short, the public interest. A

continued on page 96

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Alley cropping as a sustainable agricultural technology for the hillsides of Haiti: Experience of an agroforestry outreach project

Michael E. Bannister and P. K. R. Nair

Abstract. *Alley cropping is a form of hedgerow intercropping where fast-growing leguminous trees are planted at dense within-row spacing, with agricultural crops planted between the hedgerows. This agroforestry technology, with the hedgerows planted on the contour across the slope, appears promising for small farmers on the hillslopes of Haiti. An agroforestry outreach project operating in Haiti since 1981 has helped thousands of farmers plant hedgerows on their farms. The farmers are increasingly accepting the technology: the length of hedgerows planted by the farmers in the project area increased from 11 lineal km in 1987 to 140 lineal km in 1988. An evaluation of 50 farms where hedgerows had been installed shows that this technology results in soil conservation and microsite enrichment between hedgerows; the hedgerows also provide fodder and fuelwood. However, refinements are needed in technical aspects of hedgerow management, such as planting configurations, pruning regime, and choice of species. Moreover, soil and plant parameters as well as socioeconomic characteristics must be monitored in a systematic way in order to assess the impact of hedgerow intercropping on the sustainability of Haitian farming systems.*

Key words: agroforestry, alley cropping, Haiti, hedgerow intercropping, small-scale farming, soil conservation, sustainable agriculture

Introduction

One of the greatest challenges facing today's world is the development of sustainable land-use systems capable of meeting the basic needs of increasing populations. The magnitude of this challenge is greatest in the tropical developing countries that confront the problems of increasing deforestation, accelerated soil erosion and soil degradation, and shortages of food, fodder, fuelwood, and small timber. Land-use systems that address this challenge should fulfill the basic criteria of production of multiple outputs, maintenance of the production base (which is an essential attribute of sustainability), and social acceptability. Agroforestry is a collective name for land-use systems and technologies in which woody perennials are deliberately grown on the same land management unit as annual crops or animals.

The purposeful growing of trees and crops in interacting combinations for various objectives has been practiced worldwide for many years, especially in the tropics. Many examples of low-input agroforestry systems, in which both economic and ecologic benefits result from interactions among woody perennials and herbaceous crops or animals on the same production unit, occur in various ecological regions in the tropics (Nair, 1989; Rocheleau et al., 1988). However, only during the past decade has agroforestry "come of age," with the recognition that these age-old systems offer environmental and conservation-related benefits and the potential for sustained yield of multiple outputs (Steppler and Nair, 1987). Today, efforts are under way to develop improved agroforestry systems that encompass these beneficial attributes of traditional systems. An effort to demonstrate the applicability of the agroforestry approach to sustainable land use under difficult environmental and socioeconomic conditions is exemplified by the Agroforestry Outreach Project (AOP) in Haiti.

General background of Haiti

Haiti is located between 18 and 20 degrees north latitude and 71 and 75 degrees west longitude (Figure 1). The land area is 27,700 km^2, most of which is mountainous. There are some major coastal plains, but 63 percent of the land has slopes greater than 20 percent (Blemur et al., 1987). Most of Haiti is in the subtropical moist forest classification of the Holdridge life zone system, a system originally developed in Haiti (Holdridge, 1947). Parts of the country receive less than 800 mm of rainfall per year, but rainfall is generally at least 1000 mm, with many regions receiving more than 1500 mm per year (Ehrlich et al., 1985). Rainfall occurs mostly in the spring and fall, but local rainfall patterns vary greatly because of the varying effects of mountains. The high variability in rainfall and temperature caused by difference in topography and elevation

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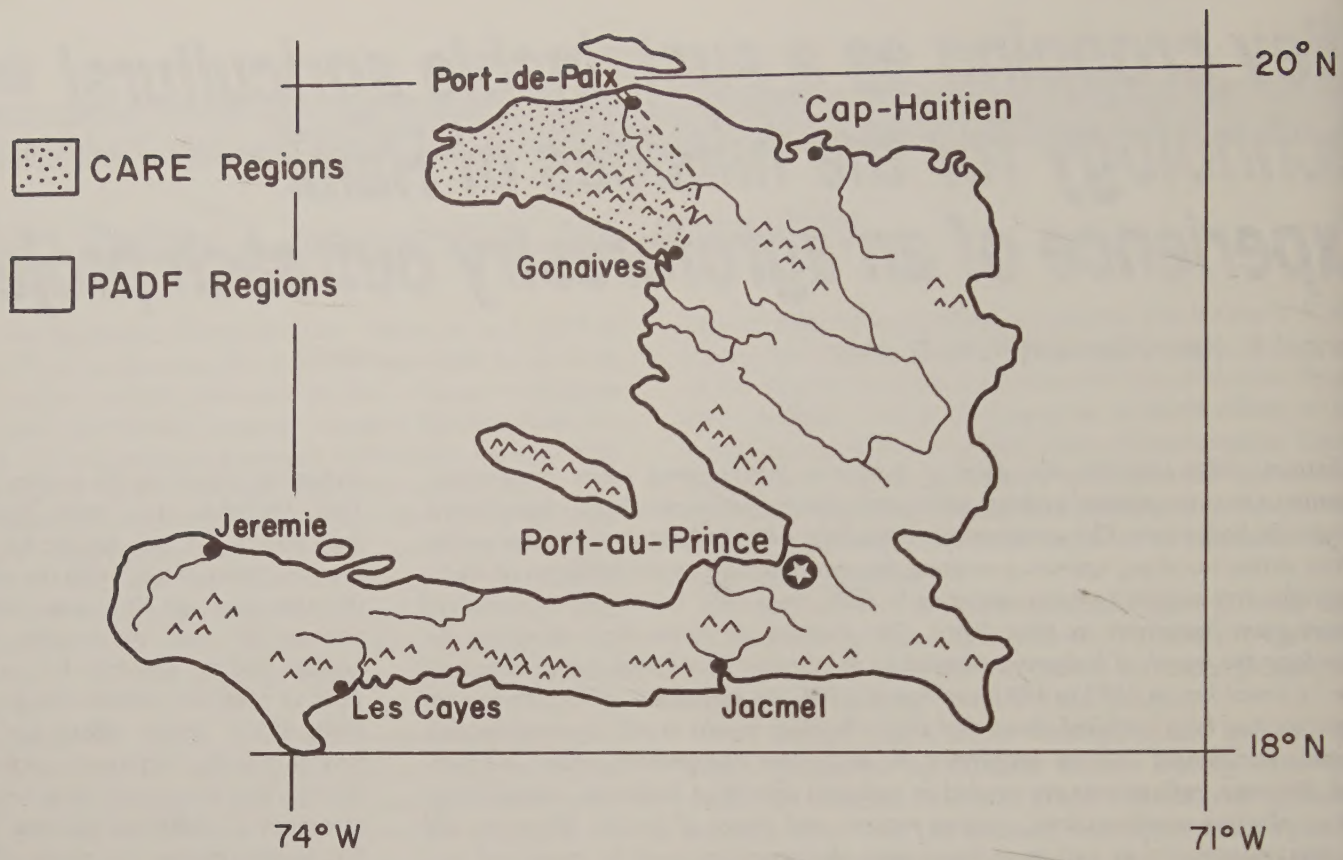

Figure 1. Map of Haiti showing project areas.

creates highly heterogeneous microclimates. Coupled with variations in soils, this causes differences in local agricultural practices and makes recommendations on appropriate agricultural technologies very location specific (Ehrlich et al., 1985).

Eighty percent of the soils of Haiti are derived from limestone formations. Many of these are degraded, shallow mollisols that are relatively fertile compared with the soils derived from igneous formations found where the overlying limestone has worn away (Ehrlich et al., 1985). The thickest hillside soils are dark red well-drained oxisols. Red-yellow ultisols have lower infiltration rates and a less permeable subsurface horizon. Younger soils include inceptisols developing in alluvium of the mountain valleys and coastal plains and shallow entisols on hillsides (Blemur et al., 1987).

History and topography have been two of the main forces shaping the structure of Haitian farm systems. The breakup of plantations after the revolution in 1804 led to scattered independent settlements based on family associations (Weil et al., 1973). The current population of over five million people lives on a land area of just under 28,000 km^2, of which the cultivated area is under 9,000 km^2, for an average density of about 160 per km^2 or over 600 per km^2 of cultivated area. Farms less than 3 ha make up more than 90 percent of all holdings; they support 88 percent of the rural population and occupy 62 percent of all cultivated lands (Blemur et al., 1987). About 80 percent of the population is rural, and most farms are on lands with over 20 percent slope. According to the criteria of the USDA land capability classification, only 11 percent of the land area falls under classes I and II (prime land), the rest being suited only to forestry, tree crops, and pasture because of steep slopes and high erodibility (Ehrlich et al., 1985).

Most Haitians are peasant farmers who depend for their livelihood on smal hillside farms, commonly called gardens During colonial times (before 1804) Haiti produced an abundance of expor crops, such as sugar cane, to help financ the campaigns of Napoleon. However there has been a steady economic declin since the 1804 revolution. Over th years, the increasing population pro duced a large labor force with very lim ited opportunities. Since land area wa limited, the person/land ratio in agricul ture increased, contributing to more la bor-intensive agricultural practices. De clining prices of export crops that wer less destructive to the soil, such as coffee caused land to be switched from peren nial to annual crops, with a resulting in crease in soil erosion (Lundahl, 1984) Haiti's population density was though to be greater than the carrying capacit of the land even in the mid-1970s (Ewel 1977). The situation is aggravated by complex set of socioeconomic problem that restrict access to education, credit

markets, and government extension services. Peasant farmers do not have access to the information and resources they need to improve their farming systems.

Soil erosion is a serious land-use problem in Haiti. Although there are no reliable erosion data at the national level, signs of erosion are easy to see: increasing exposure of bedrock, hydrologic cycles pushed to extremes of flood and drought, decreasing agricultural production, and migration of rural people to the cities (Ehrlich et al., 1985). A 1938 estimate gave an annual national loss of seven million metric tons of soil, containing eight thousand metric tons of soil nutrients. An estimated 200,000 ha had been abandoned because of erosion by 1938, with the figure reaching 500,000 ha by 1954 (Lundahl, 1979). FAO estimates that 6,000 ha of farmland are currently lost to erosion each year (Blemur et al., 1987).

Since farms are becoming smaller and more intensely cultivated, farmers cannot afford to leave land in fallow (Smucker, 1983). Continuous cropping of annuals leads to physical degradation of the soil, which decreases its capacity to absorb and store water. This in turn causes "pseudo-drought," a condition where rainfall is adequate for crop production, but moisture is not available to the crops (Ewel, 1977). Crop yields continuously decrease because of moisture stress, decreased soil fertility, and decreasing soil depth, until it becomes infeasible to cultivate and the plot is abandoned. Thus the traditional farming system in Haiti is beset with serious problems, presenting as bad a combination of both environmental and socioeconomic conditions as can be found anywhere, a situation that can be called a "worst-case scenario."

Alley cropping and its relevance to Haiti

Alley cropping, a form of hedgerow intercropping, is an agroforestry technology of considerable interest to researchers, development workers, and farmers in many developing countries. It consists of closely planted and regularly spaced hedgerows of fast-growing, repeatedly pruned trees, usually N-fixing legumes, with agricultural crops cultivated in the alleys or spaces between the hedges. The trees are pruned regularly not only to minimize shading of associated crops, but also to provide nutrient-rich, fast-decomposing leafy mulch, which when incorporated into the soil provides nutrients to the soil and crops. The deep-rooted trees facilitate nutrient recycling and, through addition of organic matter, help improve the soil's physical condition. Moreover, hedgerows planted along the contour provide effective protection against soil erosion. The effectiveness of the barrier can be increased by planting soil-binding grasses along the hedgerows, placing pruned stakes of the hedgerow trees upslope above the cut stumps, or placing thick crop residues, such as maize stover, upslope behind the hedges. The tree foliage, if not used as a mulch, can also be used as animal fodder, and by adjusting the pruning regime the trees can be managed to provide firewood.

A substantial body of research information on various aspects of alley cropping in different parts of the tropics has become available during the past five years (Attah-Krah and Francis, 1987; Budelman, 1988a, 1988b; Duguma et al., 1988; Jama et al., 1986; Kang et al., 1984a, 1984b, 1985, 1989; Kang and Wilson, 1987; Nair, 1984, 1987; Wilson et al., 1986; Yamoah et al., 1986a, 1986b; Young, 1989). Economic analyses have indicated that alley cropping, in spite of its high labor requirement, can be profitable under certain environmental conditions (Ehui, 1988). However, it has limited applicability in semi-arid conditions (ICRISAT, 1989).

Hedgerow intercropping (alley cropping) could be a technology of considerable potential for success on the hillsides of Haiti. Appropriately spaced hedgerows of suitable woody species could be an effective approach to soil conservation in areas with slopes not more than about 30 percent. (On steeper slopes, the spacing between hedgerows will have to be reduced proportionately to achieve soil conservation benefits, leading to too narrowly spaced hedgerows and too limited interspaces for crop production.) The soil-improvement potential of the mulch could be especially valuable in Haiti, where use of chemical fertilizers by peasant farmers is infeasible. The large labor force and small size of farm holdings could favor hedgerow intercropping. However, Haitian farmers also crop fields with slopes greater than 30 percent, and they commonly use the prunings from hedgerows as animal feed rather than mulch. The experience acquired over several years from a large agroforestry field project in Haiti gives valuable insight into the extent to which the suggested benefits from alley cropping are achieved under these conditions.

The Haiti Agroforestry Outreach Project

The Agroforestry Outreach Project (AOP) implemented by the Pan American Development Foundation (PADF) and CARE, and funded by the U.S. Agency for International Development (USAID), has been in operation in Haiti since 1981. The project introduced hedgerow intercropping primarily as a low-cost soil conservation technology for hillside farmers. In the summer of 1988, we evaluated the progress of the PADF part of hedgerow intercropping under AOP during its first five years. This section is based on that evaluation.

The Agroforestry Outreach Project has focused on helping farmers plant trees as a cash crop, primarily for fuelwood and construction timber. The AOP works in selected regions throughout Haiti; CARE concentrates in the dry northwest, while the five PADF regions cover the rest of the country (Figure 1). Administrative headquarters of the PADF projects is in Port-au-Prince, and each PADF region has a team leader who is a forester or agronomist. PADF works through private voluntary organizations (PVO's), usually religious groups already engaged in development work. Each regional team leader contracts with PVO's in that region to produce and deliver tree seedlings and to provide extension services to participating farmers. PADF provides financing, extension materials, technical assistance, importation of nursery materials, and training of extension and nursery personnel. Both CARE and PADF nurseries produce tree seedlings in small containers that

are easy to transport in quantity over mountainous terrain.

The original design of the project was the culmination of many years of work in Haiti by several social scientists (Conway, 1979; Murray, 1979, 1981; Smucker, 1981). Studies in the late 1970s reported the failure of conventional soil conservation projects in Haiti. Murray (1979) found that, where soil conservation activities were incorporated into the peasant agricultural cycle, short-term economic interest on the part of the farmer was usually the motivating factor. This became a central element in the design of the Agroforestry Outreach Project. AOP has adopted the premise that participating farmers own and control the disposition of trees they plant on their own land. Over 40 million trees have been planted by Haitian farmers since the beginning of AOP. These trees serve as farm capital readily converted to cash in times of need via charcoal or construction lumber.

As the project evolved during the first two years, the regional foresters were motivated to investigate the use of trees in a way that would more directly address the soil loss problem of farmers with small holdings of rapidly deteriorating agricultural land. Introduction of hillside hedgerows of fast-growing nitrogen-fixing trees such as *Leucaena leucocephala* was the response to that situation. Hedgerow technology offered a relatively low cost of establishment (compared to traditional rock wall terraces) and short-term returns of soil retention, dry season forage, and fuelwood. PADF and CARE technicians tried this system in Haiti beginning in 1984. The initial progress was slow, but a rapid expansion in 1987 and 1988 resulted in several thousand gardens having hedgerows as a part of their agricultural system.

Hedgerow establishment

During July, 1988, we visited 50 gardens in the five PADF regions whose owners had installed hedgerows. The most common hedgerow species is *Leucaena leucocephala* (Figure 2), although some farmers have tried other species, including *Moringa oleifera* and *Cassia siamea*. Hedgerows are directly seeded on the contour using an A-frame level, which uses a rock plumb suspended from the peak of a pole frame nailed or tied together in the shape of the letter A. Most of the rows we visited were withi 2 degrees of zero slope. The usual config uration is a single row of trees at ver close within-row spacing (10 cm or less) The average garden where these hedge rows have been installed has an elevatio of 237 m, soil depth of 30 cm, and slop 39 percent. There are an average of hedgerows in the garden, with a lengt of 37 m, giving an average total lengt of 185 m of hedgerows per garden. Th average spacing is 10 m between rows The garden area covered by hedgerow averages 1,365 m^2 per garden, but not al of this area is acutually affected by th hedgerows.

It is interesting to compare the charac teristics of the hedgerow gardens wit the characteristics of the gardens wher trees alone were planted (Table 1).

Table 1. Characteristics of hedgerow gardens and tree gardens.

Garden type	Elevation (m)	Slope (%)	Tillabl soil depth (cm)
Hedgerow gardens, 1988	237	39	30
Tree gardens, 1985	250	22	54

Figure 2. *Leucaena leucocephala* being established as a hedgerow, by direct seeding, in a maize field.

The hedgerow data are taken from the sample of 50 gardens we visited during July, 1988. The 1985 data are taken from a random sample of 173 gardens (stratified by administrative region) visited yearly as case studies. Although the average elevations are almost equal, it appears that, compared to trees, hedgerows are planted on steeper slopes (39 percent vs 22 percent) and shallower soils. Trees as cash crops are apparently being planted on better land, possibly because they are seen as a valuable crop. Hedgerows are planted on steep slopes to reduce soil erosion and the rapid decline in productivity, as well as to provide fodder and fuel.

Management of the hedgerows

Farmer management of hedgerows

does not yet conform to the extension program because neither the technology nor the extension program has evolved adequately. Some farmers prune the hedgerows too early, others too late. Some hedges are not yet pruned by two years of age, when they have already reached heights of 4 to 5 meters. Other hedges are pruned too early, mainly because animals are let in or the tops are cut and carried to animals. When leaves are used as fodder, the whole garden is usually not pruned at once, but in stages according to the daily demands of the animals. However, this information regarding hedgerow management comes from interviews with farmers and extension agents during a single visit in the dry season. More reliable data will have to be gathered by working with farmers during cropping seasons and by researcher-controlled on-farm trials.

A specific pruning regime is neither practiced nor recommended because the technology is new to farmers and extension agents. Pruning too late can result in heavy seeding by hedgerow trees and a tenacious surface root system between hedgerows; moreover, it will be too late for the leaves to be used as green manure to supply nutrients to the interplanted crops. Pruning too early could mean that the hedgerow trees will not have had time to develop an adequate root system before the first pruning, thus preventing them from growing back vigorously.

Most of the leaf material is used as animal feed, not as green manure. Most of the pruned branches are used as fuel, not to close breaches in the hedgerows to stop erosion. Several farmers explained that, even if they wanted to put the pruned tops behind the rows, the neighbors would steal them for fuel.

More animal damage was observed on hedgerows in fallow areas than in gardens. It is less expensive for farmers to let their animals browse on trees than to cut and carry the leaves to them. In some cases the crops are planted too close to the hedgerows. For example, some cassava was planted within 30 cm of the hedgerows. Harvest of the tubers will damage the hedgerow and the yield of cassava might be adversely affected because of above-ground and below-ground interference.

Observed benefits and problems

Hedgerows seemingly are benefiting Haitian farms. These benefits include increased slope stability, improved microsite near the hedgerows, and products harvested from the hedgerows.

In most of the older hedgerow gardens, soil is retained behind the hedgerow trees (Figure 3). In some cases the amount is substantial, especially in the central plateau sites with sandier soils. However, we could not measure quantitatively this improvement of soil physical conditions for crop growth resulting from hedgerows. Soil moisture often seemed to be greater near the hedgerows. This is similar to quantitative results reported from IITA, Nigeria (Lal, 1989). Several farmers believed that hedgerows had increased crop yields, although they could not state the exact amount of improvement. Some believed that maize responded better to application of leucaena leaves, but field beans, the other common crop of the area, responded better to chemical fertilizer.

Pruning the hedgerows produces leaf material and branches of small diameter (< 2 cm). The extension literature used by PADF extension agents advises that the leaves should be incorporated into the soil as a green manure and the branches placed just uphill from the pruned stumps to close breaches and prevent soil erosion. As mentioned earlier, the most common use of the leaves is for fodder, followed by mulch and green manure. This is logical because animal feed is scarce and the animals have a high value. Placing leaves on the soil surface as mulch is less expensive than working it into the soil as a green manure. The most common use of the pruned branches is as fuel. The small diameter material dries quickly and can be used for cooking a day or two after pruning. Sometimes the leaves attached to the branches are left intact as a convenient way to carry fodder to animals; however, these branches are not returned to the hedgerows. Finally, it is very common for farmers to allow some of the trees in the hedgerow to grow to pole size. These trees are not pruned but are harvested when needed for house construction or other activities requiring poles.

Figure 3. Contour hedgerows of *Leucaena leucocephala* established on farmers' fields facilitate the formation of natural terraces and thus check soil erosion.

Prospects for alley cropping and agroforestry in Haiti

As mentioned previously, farmers and experts alike are very interested in alley cropping. Scientists and other experts seem to have taken extreme attitudes in interpreting the rather limited research results; some people defend it excessively, while others denigrate it with equal vehemence. Benefits, costs, and drawbacks need to be weighed properly based on long-term observations before meaningful conclusions can be drawn. Quantitative data on these aspects are not yet available from the Haiti project. Therefore, the following evaluation is based on our observations and experience.

Advantages

The technical advantages of hedgerows include both their direct contribution to production (green manure, fodder, fuelwood) and their indirect contribution to some soil-related sustainability parameters (soil conservation, site fertility enrichment, and soil moisture improvement). All these benefits are inseparably associated, and more than one criterion must be used to evaluate them. Given the conditions of the project area as well as project objectives, the important indicators of hedgerow efficiency are environmental indicators (soil conservation and improved soil nutrient levels as indicated by plant growth) and crop yields near and away from the hedgerows. Together, these can contribute to an overall understanding of farm system sustainability. To determine all these variables quantitatively requires periodic monitoring over a considerable length of time by competent individuals using simple and easy methods. Despite the lack of such technical measurements, we could clearly observe changes in some of these variables.

Micro-site enrichment. Site improvement near the hedgerows is one of the best indicators of sustainability. Wherever hedgerows caused a natural terrace to be formed, a 2 to 3 m wide area upslope from the hedgerow was built up by accumulation of soil from above the slope. This was clearly evident from the physical appearance of the soil as well as by the better growth of crops in this area compared to the rest of the alley between hedgerows. The width of this "enriched microsite" varied considerably at different locations; in general, the enriched area was narrower in steeper alleys. We could also see clearly that soil moisture retention is greater in the enriched microsites than the rest of the alley.

Soil erosion characteristics. Terraces formed above the hedgerows were clearly visible in all gardens that had hedgerows at least two years old. In most places, a vertical drop of 30-50 cm just below the hedgerow was common. Terrace formation was greater where the hedgerow was thicker (more than one line of trees or trees plus grasses). Signs of erosion around trees were visible in single lines of trees where the interspaces between trees along rows had not been protected by grass strips or dead mulch. However, the extent to which any possible improvement in infiltration rate would have resulted in reduced runoff cannot be stated without technical data.

Crop growth and yield. Crop growth and yield were visibly better in the enriched microsite, but measured data were not available. A clear indication that farmers knew that crops would grow better in the hedgerow plot than the no-hedgerow plot was that in some gardens they had planted a sorghum (and sometimes maize) crop before the harvest of first season maize in hedgerow plots, whereas the adjacent, non-hedgerow plot owned/managed by the same farmer had not been planted with the second crop. We have no data on the yield of subsidiary products such as fodder and fuelwood, but their value is suggested by the fact that "anti-leucaena" farmers stole mulch from the plots of their "pro-leucaena" neighbors for use as pig fodder and fuelwood.

Problems

Too much emphasis has been placed on a single tree species, *Leucaena leucocephala*, as a hedgerow species. Insects and its potential to become a weed are risks associated with hedgerows constructed using leucaena. Neither was a serious problem in the 50 gardens we visited during July, 1988. The psyllid in sect, *Heteropsylla cubana*, has caused ex tensive devastation of leucaena in man leucaena-growing areas (Hollingswort et al., 1985; Sorensson and Brewbake 1984). We noticed psyllid insects on leu caena leaves, especially above 500 m, bu no serious damage had been done. Ac cording to one PADF team leader, th psyllids are visible during specific time of the year; they damage the termina bud, but the tree recovers quickly an does not appear to lose vigor. Howeve if the number of hedgerows expanc greatly, this equilibrium may chang This is especially important because th genetic base of hedgerow trees in Hai is probably very narrow. Resistance t pests is a highly heritable trait in mos trees. Efforts must be made to broade this genetic base by importing mor seeds and by trying more tree species i hedgerows.

Only three of the 50 gardens had area where leucaena reproduction fror hedgerows or neighboring leucaena tree threatened to take over the garden as weed. The seedlings were not very tal and the owners did not seem to be wor ried about them. They intended to re move them during land preparation fo sowing crops. Leucaena could take ove a garden if the hedgerows are abar doned. Although weediness is not yet problem, it is a possibility. PADF exter sion agents should make this a part c their extension package.

Another problem is farmers' wide spread tendency to remove all leave from the hedgerow garden as animal foc der. If this practice is continued for a fe years in a garden, the nutrients preser in the leaves will be mined from the site causing soil fertility to decline. We d not know yet how much material ca safely be removed as fodder and ho much should be incorporated into th soil.

Other agroforestry options

Too much emphasis on hedgerows car be counterproductive. Hedgerows have their limitations, too--they are not a pan acea. On extremely steep slopes (over 5(percent) and very poor calcareous anc rocky sites, where crop production is in

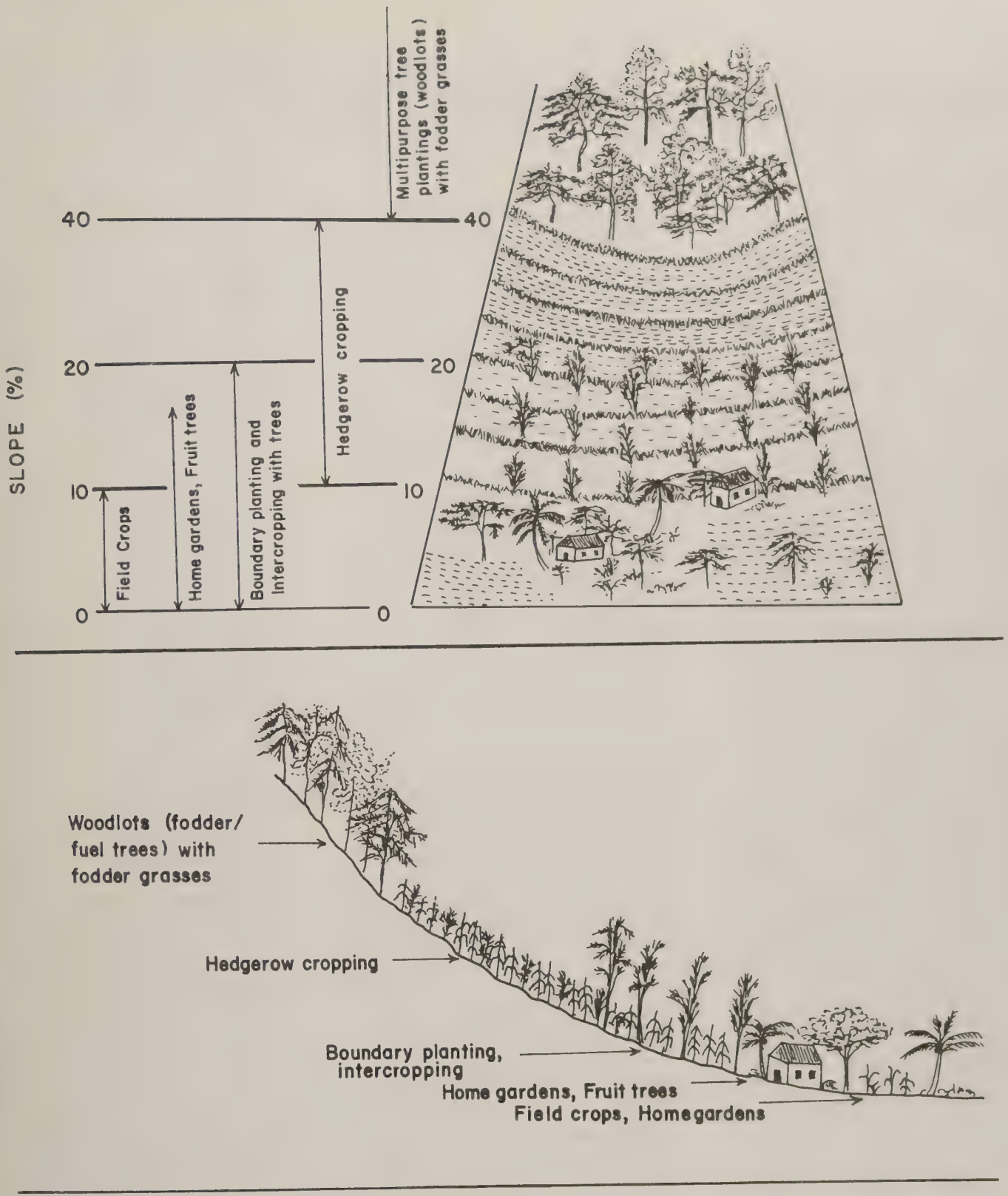

Figure 4. Schematic presentation of agroforestry approaches to sustainable land use in the sloping farmlands of Haiti.

advisable, widely spaced hedgerows with crops in between will not be the best option. Appropriate agroforestry alternatives need to be considered; some options are listed below.

Fruit trees. A large variety of indigenous fruit trees play a major role in the nutrition and cash economy of rural people in Haiti. Examples are different types

of mangoes, breadfruit, guava, and papayas. No serious effort has been made to improve them or integrate them scientifically into farming systems; such efforts are worth serious consideration.

Intercropping and other forms of tree and crop associations. Some tree species, such as *Moringa oleifera* and most fruit trees, are highly valued by local farmers; but they can be poor hedgerow species because they respond poorly to intra-row interference. The best strategies for their integration on farmlands are planting them as borders around field plots or scattering them on farms so that intercropping is possible. Tree species that are indigenous to Haiti, or that have a long history of adaptation, need to be given more prominence in these efforts.

Woodlots. Hedgerows for alley cropping are of limited applicability and doubtful value in seriously eroded, very poor, and extremely sloping (>50 percent slope) lands. A better technology for such lands would be to establish woodlots that produce fuelwood, small timber, and fodder and mulch for cut-and-carry systems. Woodlots can improve such sites in the long run. Recommended tree species include all species that can be used for hedgerows and others such as *Acacia auriculiformis*, *A. mangium*, *Azadirachta indica*, *Casuarina equisetafolia*, *Cupressus lusitanica*, *Grevillea robusta*, and *Tamarindus indica*.

Short rotation fallows. Some soil-improving, fast-growing leguminous woody species do not live long enough to be grown as hedgerows. Many *Sesbania* species are in this category, such as *S. sesban*, *S. aculeata*, *S. bispinosa*, and *S. grandiflora*. In some parts of Haiti, the topography and other land characteristics are so unfavorable that farming is too risky, with crops failing as often as four out of five years. These lands may be brought under short rotation fallows (2 to 3 years) to alternate with cropping cycles that will considerably improve the site and conserve soil. Farmers who are accustomed to frequent crop failures will probably be willing to try such approaches.

Figure 4 presents schematically an "ideal" site use plan for the sloping farmlands of Haiti incorporating these agroforestry options. Agroforestry efforts should encompass these different technologies rather than concentrating on any one technology, however promising it might appear.

Evaluation

We believe that the benefits of the project far outweigh the drawbacks and limitations. The project has made substantial progress and has had considerable impact. The advantages of this improved agroforestry approach are just being understood by farmers, and the barrier of farmers' initial reluctance to accept new technologies, which usually is difficult to cross, is just being broken. Farmers' enthusiasm to plant hedgerows is a clear indication of the project's success. PADF recorded 11 lineal km of hedgerows installed in 1987 in its five regions, which rose to 140 lineal km in 1988 (Hunsberger, 1989).

The criteria used to measure the success of such projects must be defined realistically and the goals set within meaningful limits, especially under such severe conditions. Development administrators, donors, and scientific evaluators should not have illusions about any miraculous transformation of Haitian peasant agriculture, which now is at very low levels of subsistence farming, into prosperous scientific farming systems within the relatively short life span of a development project. The effects of the project should be compared not only with the situation at the start of the project, but also with what the situation would have been had there been no such project. Based on periodic field observations since the beginning of the project, the project staff believes that in general the quality and productivity of land not covered by the project have declined over the years compared to the project area. Conventional methods of economic analyses, project evaluations, and statistical research techniques may not be able to accommodate the objectives of multiple-output, integrated, peasant farming systems. Therefore, the results of such evaluations and assessments need to be reviewed with caution until more suitable analytical methods become available and are accepted.

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RESOURCES

A Handbook and Videotapes on Insect Scouting in Corn, Soybeans & Alfalfa are available from the University of Nebraska. The tapes are "Corn" ($29.95); "Soybeans/Alfalfa" ($29.95); or "Corn, Soybeans, and Alfalfa" (two together, $50). The Field Scouting Manual (revised in 1990) is $25. Order (adding tax and making check payable to the University of Nebraska) from Field Scouting, 104 Agricultural Communications, University of Nebraska, Lincoln, NE 68583-0918.

A Citizen's Guide to Clean Water is a 50-page booklet developed to make provisions of the Clean Water Act more accessible to citizens. For free copies, contact the Izaak Walton League of America, Citizen's Clean Water Guide, 1401 Wilson Boulevard, Level B, Arlington, VA 22209.

CIAS Connections is a new newsletter from the Center for Integrated Agricultural Systems at the University of Wisconsin-Madison. The first issue reports on program goals and research and decribes a new (in draft) high school curriculum in sustainable agriculture. Contact the Center for Integrated Agricultural Systems, University of Wisconsin-Madison, 1535 Observatory Drive, Madison, WI 53706.

Common Sense Pest Control Products & Services Directory lists 200 manufacturers of "least-toxic pest control" products. Copies are $4 postpaid from the Bio-Integral Resource Center, P.O. Box 7414, Berkeley, CA 94707.

The Cerealist, a new publication of the KUSA Society, is a comprehensive, in-depth publication on edible seedcrops and grains. It is available to members of the Society (dues are $25 yearly), P.O. Box 761, Ojai, CA 93023.

Rodale Research Reports Catalog is available from the Rodale Research Center at 611 Siegfriedale Road, Kutztown, PA 19530.

"Evaluating the Effectiveness of Field Demonstration Programs" is the result of surveys in 1988 and 1989, conducted by Iowa's statewide integrated farm management demonstration program. It is available at Iowa State University, 103 Morrill Hall, Ames, IA 50011, (515) 294-0701.

"Farming for Profit and Stewardship" is a proceedings volume from a conference in Idaho, Washington, and Oregon. It is priced at $4 through the Department of Agronomy and Soils, Washington State University, Pullman, WA 99164.

Sustainable Agriculture in Minnesota is a study of profitable alternative farming methods. A variety of on-farm research projects are described. Those interested in the report should write directly to Minnesota Department of Agriculture, 90 West Plato Boulevard, St. Paul, MN 55107.

Pests of the Garden and Small Farm is a users' guide with 250 color photos, reference tables, and guidelines for identification of pests. The 288-page comprehensive book by Mary Louise Flint, Ph.D., is sold through ANR Publications, 6701 San Pablo Avenue, Oakland, CA 94608, (415) 642-2431, for $25.

Clean Earth Guide to Ohio's Certified Organic Farms & Gardens is a 10-page consumer guide to growers certified by the Ohio Ecological Food and Farm Association. The guide is $3 from OEFFA, 65 Plymouth Street, Plymouth, OH 44865.

A Study on Organic Marketing is being offered by the Kansas Rural Center for $5. This report will be useful for those processing and marketing organic foods and produce and was endorsed by the U.S. Department of Commerce. A business plan, and other components of marketing strategies, are parts of this report. It may be obtained from the Kansas Rural Center, P.O. Box 133, Whiting, KS 66552.

Farming with reduced synthetic chemicals in North Carolina

Molly Anderson

Abstract. *The primary objectives of this study were to describe the various pest control and soil fertility management strategies used by North Carolina farmers and to characterize the types of farms and farmers using each strategy. In 1988, a survey was mailed to farmers who had shown interest in alternative methods and a randomly selected control group of conventional farmers. Cluster analysis on crops, inputs, and cultural practices used by crop farmers in the combined sample showed that they fall into three distinct groups. Very few members of the first group apply standard synthetic fertilizers and pesticides. Instead, more than three-quarters of them use cover crops, compost, organic mulch, commercial fertilizers and pesticides labeled as "organic," resistant varieties, hand weeding, mechanical cultivation, scouting, and biological pest controls. More than half of the second group did not use any nutrient and pest management inputs or practices except synthetic fertilizers, herbicides, and lime. More than three-quarters of the third group reported use of synthetic fertilizers, synthetic herbicides, and lime, but also employed most of the cultural practices reported by alternative farmers. However, they less frequently used labor-intensive practices (such as manuring, mechanical cultivation, and hand weeding) and information-intensive practices (such as scouting and companion planting). Information sources, concerns about farm chemicals, and length of farming experience discriminated better than other socioeconomic factors and farm characteristics between farmers who use conventional chemical inputs and those who use alternative practices. Group 1 farmers differed from Group 3 farmers most sharply in that they rank the cost of pest control products and their extension agents' advice lower, have lower farm incomes, read more information sources promoting reduced synthetic chemicals, own more of the land they operate, and have less farming experience. The only factors significantly discriminating Groups 1 and 2 were that Group 1 farmers rank the importance of their extension agents' recommendations lower and effects of chemical products on birds and wildlife higher, read more reduced-chemical information sources, and have less farming experience.*

Key words: low-input agriculture, fertilizers, pesticides, information sources, values

Introduction

Why do some farmers choose to use no synthetic pesticides and fertilizers, and what do they do instead to control pests and enhance soil fertility? What kinds of farmers choose different fertilization and pest control strategies? Although recent farmer surveys show that most farmers in some parts of the country would like to adopt safer alternative products and practices, most farmers continue to use synthetic farm chemicals. Learning why and how some farmers cut back on their use of synthetic chemicals will help efforts to lower input costs, reduce agricultural pollution of water and air, and meet burgeoning demands for pesticide-free foods.

Farmers' decisions to substitute alternatives for conventional synthetic chemicals, and the particular practices they use, have been studied frequently. Most studies identify and describe a group of unusual farmers, most commonly organic or "transitional" farmers. Sometimes this group is contrasted with "conventional" farmers, but organic farming is seldom analyzed as one of several strategies for using synthetic chemicals and their alternatives. Descriptions of organic farming operations usually include factors such as farm size, farm income, whether the farm is owned or rented, farmer's age, educational level, and information sources. These studies give a fairly consistent picture of typical organic farmers from many parts of the U.S.: they have smaller farms than their "conventional" counterparts, lower farm incomes, less farming experience, and more formal education. They rely on practices such as crop rotation, cultivation, mulches, scouting, cover crops and animal manures to control pests and maintain soil fertility. Unlike farmers using conventional chemicals, they do not often go to extension agents or farm supply dealers for information about pest control and soil fertility. Some studies show slight deviations from these patterns, but such regional differences are to be expected. Also, different researchers have used different selection criteria for deciding which farmers to include; so the studies have covered farmers with different farm sizes, kinds of crops, and practices.

Descriptions of organic farmers sometimes include less easily quantified factors, such as beliefs about the advantages and disadvantages of organic farming, but qualitative characteristics have seldom been combined with farm or demographic characteristics to find what contributes most to farmers' decisions to abandon mainstream practices. Some early studies emphasized that organic farmers choose unusual practices for pragmatic financial, health, or agro-

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nomic reasons (Wernick and Lockeretz, 1977; Marston, 1979); others (Oelhaf, 1978; Youngberg, 1978; USDA, 1980) found that they are motivated by more abstract goals, such as environmental quality or self-sufficiency. More than a decade later, these viewpoints have not been reconciled entirely. Recent publications emphasize technical and policy barriers to adopting farming systems with less reliance on synthetic chemicals. But if organic farmers' production choices are rooted in values that are not shared by most farmers, making more technical information available or removing policy barriers will not be sufficient to effect widespread changes in farming practices. A system attractive to a farmer who is already predisposed to environmentally benign agriculture may be unappealing to a farmer without strong environmentalist values because it may just look like bad farming.

Farmers who already use alternative farming methods are an increasingly important part of the farming population. They can provide agricultural products without much of the pollution that creates such an unwelcome public burden. Understanding who they are and why they choose to use lower levels of synthetic chemicals should help in designing policy and educational programs to encourage more widespread acceptance of alternative practices. This information is needed for all geographic regions of the U.S., but no survey-based studies of alternative farmers have been done in the South. This is a serious omission because farmers in the South use disproportionately large amounts of synthetic chemicals (Healy, 1985), especially insecticides (Suguiyama and Reichelderfer, 1987). The long growing season, lack of killing frosts, and abundant rainfall in parts of the region are conducive to consistently high pest populations or sporadic outbreaks unless powerful pesticides are applied. Highly leached soils are prevalent in the region and must be supplemented with several nutrients. This is most easily done with synthetic fertilizers. Therefore, farmers who avoid synthetic chemicals for pest control and fertilization are rejecting a fundamental prop of Southern agriculture.

Scope

This study characterized the pest control and fertilization strategies used by farmers in North Carolina, a leading agricultural state of the South whose primary crops (tobacco, forest products, greenhouse and nursery products, soybeans, vegetables, peanuts, and corn) are highly chemical intensive. A second objective was to discriminate types of farms and farmers using each strategy. Because farmers who use alternatives to synthetic chemicals were of primary interest, farmers likely to use these methods were oversampled from the population of all North Carolina farmers. Cluster analysis objectively defined strategies, or sets of practices and inputs that typically are used together. I did not use the more common ways of identifying alternative farmers, such as membership in organic farming organizations, subscription to alternative farming magazines, or avoidance of particular products, because there is no guarantee that all farmers in samples selected by these criteria have similar management practices. Cluster analysis distinguished groups according to both what farmers do and what they avoid but not their social affiliations or categories set up by the investigator.

Contrasting farm and farmer characteristics among the groups differentiated by cluster analysis showed how North Carolina farmers using very low inputs of synthetic farm chemicals compare with other kinds of farmers in this state and with typical organic farmers from other states. I was especially interested in farmers' values and concerns about using farm chemicals because I expected that farmers choosing a strategy with very low chemical inputs would have stronger concerns about health and environmental quality than other farmers and that such concerns set these farmers apart from others better than do farm attributes. In comparing groups, I first used single-variable statistics to examine variables independently, then logistic regressions to examine simultaneously all variables that were most important in single-variable analyses. This method extracted the farm characteristics and socioeconomic attributes, including concerns about farm chemicals, that best differentiate farmers using different inputs and practices.

Methods

Interviews and survey

This work consisted of two phases: interviews with organic farmers and a mail survey. I interviewed five farmers approximately five times each between August, 1986, and December, 1987. These interviews were informal meetings focusing on each farmer's opinions about successful farming and ways to cope with production problems specific to farming with low synthetic chemical inputs (Anderson, 1989). I also studied organizations promoting organic or reduced-chemical farming in North Carolina to understand better the social setting of alternative farming. I selected farmers to interview from recommendations of board members of the largest local organic farming group, the Carolina Farm Stewardship Association (CFSA) and of organic farmers themselves. I chose organic farmers to interview because they are at the low end of the spectrum of farm chemical use and because they self-identify much more than "reduced-input" farmers, for example. Interviews and study of farming organizations were necessary to tailor a survey to the practices and concerns of local farmers rather than imposing preconceptions derived from studies of farmers in other regions.

I mailed a 12-page survey congruent with Dillman's Total Design Method (Dillman, 1978) in early summer, 1988, to farmers on two lists described below. Non-respondents received letters and duplicate questionnaires twice after the initial mailing. The survey asked about crops and livestock sold in 1987, practices used for nutrient management and pest control, preferences for chemical-intensive versus alternative production methods, changes in use of agricultural chemicals over the last five years, concerns about agricultural chemicals, and socioeconomic characteristics. I assessed use of synthetic chemicals by asking whether farmers used commercial syn-

thetic fertilizers, herbicides, insecticides, fungicides, or nematicides in 1987, with an example in each instance of a commonly used product. To measure concerns about agricultural chemicals, farmers were asked to rate each item on a list I had compiled during interviews and study of farmer organizations. Possible ratings were very important, somewhat important, not important, or not applicable. The farmers also chose three concerns from the list that were most important to them. Spaces were provided in most sections of the questionnaire for write-in responses, such as concerns or management practices not already included in the questionnaire.

The first list of names was compiled from several likely sources of potential reduced-chemical-input farmers: farmer-members of the CFSA or the North Carolina Organic Crop Improvement Association, farmers who had asked about the CFSA's organic certification program, farmer contacts of an herb broker who solicits organic herbs, North Carolina commercial farm-operator respondents to a national survey conducted by an alternative farming magazine, and self-identified farmers who attended the 1986, 1987, or 1988 North Carolina Alternative Farming Field Days. This list of 275 names included most farmers in this state attempting to eliminate or greatly reduce their inputs of synthetic farm chemicals.

The second list, which was intended to consist mainly of conventional farmers, contained names of farm operators supplied by the Agricultural Stabilization and Conservation Service in 11 contiguous counties in central North Carolina. This was the region most heavily represented in the membership of statewide organic farming organizations and included the home counties for the five intensively interviewed farmers. From this list, I randomly selected 330 farmers.

Response rates were 70 percent from the potential reduced-chemical-input source and 53 percent from the potential conventional source. I deleted surveys from further analysis if the respondent was no longer farming or sold less than $1000 of agricultural products in 1987. The two lists respectively contributed 114 and 45 usable cases. Of these 159 farm operators, 148 raised crops, either alone or with livestock; the other 11 raised only livestock. Descriptive statistics reported in this paper included the 148 crop and crop/livestock farmers. The logistic regressions used 141 of these farmers whose reponses had no missing data.

Cluster analysis

I did a cluster analysis to identify ge eral management strategies, using d chotomous data on pest control and fe tilization practices, crops, and livestoc These included all items in Tables 1 an 2 plus a few additional products fro the survey which were infrequently use

Table 1. Most Commonly Reported Inputs and Practices.

	Total Number of Farmers n = 148	Percent of Farmers in Each Group* Alternative n = 54	Part-time Conventional n = 46	Full-time Convention n = 48
Nutrient Additions (some also help control pests):				
Lime	110	**76**	**63**	**83**
Crop rotations	108	**89**	26	**100**
N in commercial synthetic fertilizer	97	24	**80**	**98**
P in commercial synthetic fertilizer	87	24	**65**	**92**
K in commercial synthetic fertilizer	87	22	**65**	**94**
Commercial "organic" fertilizer	80	**80**	30	23
Manure from on farm	74	**59**	48	42
Compost	68	**91**	28	13
Manure from off farm	48	**69**	17	6
Pest Control (some practices also supply nutrients)				
Cover crops	115	**96**	39	**94**
Mechanical cultivation	108	**91**	41	**83**
Insect- or disease-resistant varieties	107	**81**	43	**88**
Hand cultivation	105	**100**	43	**65**
Scouting	96	**80**	43	**69**
Double- or intercropping	73	**69**	11	**65**
Organic mulch	72	**91**	33	17
Plantings timed to avoid insects or disease	69	**61**	13	**63**
Spot application of herbicides	67	20	**54**	**65**
Commercial "organic" or plant-derived pesticides	64	**81**	26	17
Companion planting	57	**78**	9	23
Commercial synthetic herbicides	52	4	**54**	**77**
Commercial synthetic insecticides	39	4	24	**54**

* Boldface shows inputs or practices reported by at least half the farmers in the group.

Table 2. Crops and Livestock.

	Percent of Farmers in Each Group Alternative n = 54	Part-time Conventional n = 46	Full-time Conventiona n = 48
Tobacco	0	9	65
Corn for grain or silage	13	7	77
Soybeans	7	2	60
Small grains	15	9	69
Pasture or hay	43	63	69
Vegetables	69	7	23
Fruits	28	7	0
Ornamentals or forest products	39	30	2
Greenhouse or nursery products	7	15	0
Livestock for sale	32	64	56

by farmers in any group: commercial fungicides, nematicides, grain storage fumigants, *Bacillus thuringiensis*, and plastic mulch. Crops and livestock entered the cluster analysis, not just practices, because appropriate practices often depend on enterprise type. I tested the reliability of clusters by forcing the analysis to split the data into two, three, and four groups. The same independent variables had the highest F-ratios in each analysis, and division into two or four clusters collapsed or subdivided categories present in the three-way analysis. I chose the three-way split because it gave approximately equal-size groups large enough for comparative statistics. I used chi-square analysis to test whether the distribution of individual variables was significantly different among the three groups, which I labeled alternative farmers, part-time conventional farmers, and full-time conventional farmers, for reasons explained below.

Logistic regressions

Logistic regressions suggested which characteristics were most important in distinguishing farmers using different management strategies. Polytomous logistic regression was the appropriate procedure for this study because the variable of interest was the likelihood of a farmer being assigned to one of three groups, rather than the more usual choice of two categories. In this procedure, one category is arbitrarily selected as the reference and the other categories are individually compared to it. I selected alternative farmers as the reference category. The dependent variables for the first and second regression equation in each model are the log of the probability of a farmer being respectively a full-time conventional or part-time conventional farmer, divided by the probability of being an alternative farmer.

The first model contained socioeconomic variables and farm characteristics. It also included information sources, represented with a dummy variable showing whether the farmer frequently reads magazines or books promoting organic or reduced-input farming. I constructed this variable from responses to several questions about information sources the farmer reads frequently. I reduced the number of socioeconomic and farm variables and information sources because a logistic regression model with all of these variables from the survey failed to converge. This problem is most likely when variables included in a model are too numerous for the sample size. I selected variables to retain that were objective aspects of the farm operation and most commonly included in sociological studies of the adoption of new agricultural techniques. I excluded variables I judged to be most subjective, since I also wanted to test whether subjective factors would significantly improve a model that originally contained only objective variables. I transformed all continuous variables into ranges of 1 to 4 (farm size, farm income, and proportion owned to operated land) or 1 to 3 (farming experience) before including them in the models.

The second model added three concerns about farm chemicals to the variables in the first model that had a significant effect at $p < .05$ (one-tailed t-tests) on the odds of being an alternative farmer versus being in one of the other groups. To select concerns about agricultural chemicals to include in the second model, I used a stepwise procedure with logistic regression on concerns alone, as described later. Concerns entered the logistic regression as importance scores scaled from 1 to 4.

The presentation of logistic regression results usually includes the change in predicted probability of the dependent variable caused by a small change in each independent variable, most often evaluated at their mean values. I did not do this calculation because it would have been inappropriate with the intentionally non-representative sampling method chosen in this study. Farmers came from two separate sources, and the averages of variables across the entire sample were not meaningful. Therefore, changes in predicted probabilities accompanying changes in those values could not be interpreted. For this study's logistic regressions, I report the coefficients of variables in regressions of each conventional group compared with the alternative farmer group, with their t-statistics and significance levels. These show which combinations of variables discriminate alternative farmers from other types and whether each variable's effects are positive or negative. I tested the significance of adding selected variables to a model with the following formula:

$$c = -2 \log(L_2/L_1)$$

where c follows the chi-square distribution, L_2 is the value of the fitted likelihood function for the smaller model and L_1 the value of the fitted likelihood function for the larger model (Aldrich and Nelson, 1984).

Chemical-use strategies used in North Carolina

Three strategies of pest control and nutrient management were delineated by cluster analysis (Table 1). Although the three groups of farmers using different strategies were defined by their practices, I named them for convenience by other variables to be discussed later. I labeled the first group "alternative" farmers (n=54) because they rely heavily on alternatives to synthetic chemicals. Only 4 percent of farmers in this group use synthetic herbicides and insecticides, and fewer than one-quarter reported use of either N, P, or K synthetic fertilizers. I labeled the second group "part-time conventional farmers" (n=46) in contrast to the third group, "full-time conventional farmers" (n=48). Both groups reported customary use of conventional synthetic fertilizers and herbicides, with more than half the farmers in these groups using both types of products; but they are very different in their reliance on off-farm income.

Full-time conventional farmers reported many management techniques used by alternative farmers, such as crop rotations, cover crops, insect- and disease-resistant varieties, and mechanical cultivation. However, fewer than half the part-time conventional farmers reported using any soil fertility management or pest control practices other than synthetic fertilizers, lime, or synthetic herbicides. More full-time conventional than alternative farmers raise livestock commercially (Table 2), but fewer full-time conventional farmers apply manure to

their fields. This is consistent with their general avoidance of labor-intensive practices, such as mulching or composting, when chemical alternatives are available. Also, they are less likely than alternative farmers to use non-chemical methods requiring specialized or uncommon information, such as companion planting or scouting. The only deviations from this pattern are in their use of crop rotations, insect- or disease-resistant varieties, and plantings timed to avoid pests or disease.

The three groups also differ in the commodities they sold in 1987, since this entered the cluster analysis. The crop category reported most frequently by alternative farmers is vegetables, followed by pasture, ornamentals or forest products, and fruit (Table 2). Part-time conventional farmers primarily raise pasture or hay and ornamentals or forest products. Full-time conventional farmers raise corn for grain and silage, pasture or hay, small grains, tobacco, and soybeans. Livestock (primarily beef) or animal products were sold more frequently in 1987 by part-time and full-time conventional farmers than by alternative farmers. The choice of livestock and forage helps explain part-time conventional farmers' low use of soil fertility and pest control techniques and is compatible with their part-time operations.

These results show that there are three distinct farming strategies with respect to choice of crops, livestock, nutrient management, and pest control. The part-time conventional farmers are as unlike full-time conventional farmers as alternative farmers and, therefore, should not be combined with full-time conventional farmers to create a single "conventional" group to contrast with alternative farmers. Alternative farmers cannot be described accurately as "low-input" farmers; they use as many types of products and practices as full-time conventional farmers. "Low-input" would be a more meaningful descriptor for part-time conventional farmers with pasture/livestock systems, or perhaps poor farm managers. Part-time conventional farmers are not "transitional," even though they share characteristics with both of the other groups. They do not appear to be moving away from or toward alternative farming. In fact, a higher proportion of full-time conventional farmers than part-time conventional farmers reported that during the last five years they had stopped using synthetic fertilizers, herbicides, or insecticides on at least one crop.

Who uses each managemen strategy?

Socioeconomic characteristics and information sources

Farmers with different farm manage ment strategies have markedly differen socioeconomic attributes (Table 3). Al ternative and part-time conventiona farmers are similar in most ways, al though the latter are more likely to hav farming backgrounds. Farmers in both these groups tend to have much smalle farms and farm incomes than full-tim conventional farmers and earn most o their household incomes from off-farm work. They own a much higher propor tion of the land they operate. They hav more formal schooling: 65 percent of al ternative farmers and 51 percent of part time conventional farmers have earne an undergraduate or higher degree com pared to only 36 percent of full-time con ventional farmers. More full-time con ventional farmers than other types grew up on a North Carolina farm, operat the farms where they grew up, and neve worked outside the state or in anothe full-time occupation besides farming. Al socioeconomic traits reported above ar significantly different ($p < .01$) amon

Table 3. Socioeconomic and Farm Characteristics.

	Alternative n = 54	Part-time Conventional n = 46	Full-time Conventional n = 48	p
Total area operated (median)	4 ha	15 ha	91 ha	.00
Owned land as proportion of total area farmed	80%	80%	50%	—*
Gross farm income (interval containing the median)	$2,500–$10,000	$2,500–$10,000	$40,000–$70,000	.00
Proportion of total household income from off-farm work (■ shows interval containing the median)				—*
0–25%	32%	21%	56% ■	
25–50%	6%	21%	21%	
50–75%	8%	5%	9%	
Over 75%	54% ■	52% ■	14%	
Farmers with no income besides farming	30%	20%	64%	.00
Gross household income (interval containing the median)	$20,000–$40,000	$20,000–$40,000	$20,000–$40,000	.60
Age (average)	44 yr	50 yr	48 yr	.37
Farming experience (average)	8 yr	16 yr	22 yr	.00
Educational level (category containing the median)	BS or BA degree	BS or BA degree	Some college, trade school, or apprenticeship	.00
Grew up on a farm	41%	62%	91%	.00
Operates the farm where he or she grew up	37%	39%	69%	.00
Had other full-time occupations besides farming at any time	91%	86%	64%	—*
Worked outside North Carolina	72%	59%	26%	—*

* Probability was not calculated because of excessive numbers of sparse cells.

groups of farmers, with the widest gap between alternative and full-time conventional farmers.

Information sources related to farm chemicals also are very different among groups of farmers. Alternative and part-time conventional farmers tend to have more sources in common with each other than do part-time and full-time conventional farmers, although both part-time and full-time conventional farmers read more specific crop and livestock magazines than do alternative farmers. Both conventional groups rely most often on their county extension agent as their main source of advice about agricultural chemicals, compared to only 13 percent of alternative farmers (Table 4). This may help explain the pattern of full-time conventional farmers more frequently using crop rotations, insect- and disease-resistant varieties, and plantings timed to avoid pest problems. Information and assistance for these practices are readily available from county extension agents or farm supply dealers (the second most important information source for full-time conventional farmers), in contrast to information about practices which are used by more alternative farmers, such as companion planting or making compost. Full-time conventional farmers also may derive greater benefits, in relation to the amount of time and money they invest, from rotations, pest-resistant varieties, and carefully timed plantings.

Alternative farmers are much more likely than full-time conventional farmers to turn to farming magazines for advice. More than one-third reported that magazines, institutions, or books promoting reduced-input farming are their most important reference regarding chemical use. Although full-time conventional farmers are less likely than part-time conventional farmers to report that farm magazines are their most important source of information, more of them claimed that they frequently read selected popular farm magazines such as *Progressive Farmer* and *Farm Journal*. Full-time conventional farmers strongly prefer advice from personal contacts such as an extension agent or farm supply dealer. Since most of them farm full time, it is likely that they have more opportunities for contact with these people than part-time conventional farmers do. No full-time conventional farmers said that magazines, institutions, or books promoting reduced-input farming are their most important source of information about farm chemicals, although 25 percent of this sample read these magazines and books frequently. These sources are more important to the part-time conventional farmers, 13 percent of whom said they were most important and 37 percent of whom read them frequently.

Previous studies of information sources have consistently found that organic farmers are dissatisfied with traditional agricultural information sources for advice on dealing with their special production problems (Wernick and Lockeretz, 1977; Blobaum, 1982; Altieri et al., 1983; Baker and Smith, 1987; Madden, 1988). The most important sources reported in other studies were organic product salesmen (Wernick and Lockeretz, 1977); other organic farmers (Blobaum, 1982); and farming magazines, books, or newsletters (Baker and Smith, 1987; Madden, 1988). Few alternative farmers in this study claimed that other farmers or organic dealers were most important to them. This difference may reflect less cohesive social networks among alternative farmers in North Carolina compared with other regions or less market penetration in this state by organic suppliers.

Table 4. Most Important Information Sources about Use of Agricultural Chemicals.

	Percent of Farmers in Each Group*		
	Alternative n = 54	Part-time Conventional n = 46	Full-time Conventional n = 48
Extension agent	13	38	43
Farming magazines	32	23	5
Farm supply dealer	6	18	36
Other growers	13	5	0
Organic farm supply companies	8	0	0
Books and periodicals	6	3	2
Magazines, institutions, or books that promote reduced-input farming (includes some items above)	39	13	0

* Columns add to less than 100% because of write-in responses (not shown).

Concerns about farm chemicals

The three groups are similar in their primary concern about using farm chemicals: farmers from all groups most often placed "whether the product might be harmful to my health or my family's health" among their three most important concerns (Table 5). This issue was especially important for the alternative farmers. Rankings for most items are significantly different ($p < .05$) among the three groups of farmers.

Alternative farmers are much more likely than other farmers to include environmental impacts among their top three concerns. After personal health, the next most important items to this group are groundwater quality, soil benefits, effects on birds or other wildlife, and air quality. At least 20 percent of these farmers placed each of these concerns among their top three. Groundwater pollution was the only environmental impact eliciting an equally strong response from both conventional groups. Reducing harmful environmental effects is weakly or negatively correlated with yields or expected income from farm operations. In contrast to alternative farmers, both conventional farming groups reported that factors directly affecting their own health or financial costs are more important to them than general environmental effects.

Many studies of environmental concerns among rural populations have shown that rural residents and farmers tend to have anti-environmental attitudes (reviewed in Buttel et al., 1987). North Carolina alternative farmers seem

Table 5. Rankings of Concerns about Agricultural Chemicals.

	Percent of Farmers Ranking Item among Top Three Concerns			
	Alternative n = 54	Part-time Conventional n = 46	Full-time Conventional n = 48	p
Whether the product might be harmful to my health or my family's health	72	52	58	.006
Whether the product might affect groundwater quality	44	24	21	.018
Whether the product is good for the soil	33	17	13	.027
Whether I have had success with the product before	2	26	38	.000
Whether the product might be harmful to birds or other wildlife on my farm	32	20	6	.006
Whether the product might affect my livestock's health in a negative way	6	33	15	.001
Whether the product makes my crops healthier	6	20	21	.054
Cost of the product	4	7	33	—*
Whether the product might affect air quality	20	4	6	.017
Whether state or federal laws prohibit use of the product	0	9	10	—*
Whether the agricultural extension agent recommends the product	0	11	4	—*
Whether my customers prefer that I use or don't use the product	6	4	2	—*
Whether the product is recommended by other people (write-in response)	2	2	0	—*

* Probability cannot be calculated because of excessive numbers of sparse cells.

Table 6. Logistic Regression of Group to which Farmer Belongs on Socioeconomic, Farm and Information Source Variables (n = 141).

Full-time conventional farmers contrasted with alternative farmers:

Parameter	Coefficient	t-Statistic	p
Farm size	.55	1.59	.057
Farm income	.97	2.94	.002
Farming experience	1.05	2.21	.014
Proportion owned to rented land	−.79	−3.04	.0015
Whether farmer frequently reads organic or low-input magazines or books	−3.14	−4.66	<.0001

Part-time conventional farmers contrasted with alternative farmers:

Parameter	Coefficient	t-Statistic	p
Farm size	.25	.89	.195
Farm income	.20	.77	.229
Farming experience	.54	1.59	.057
Proportion owned to rented land	−.09	−.42	.337
Whether farmer frequently reads organic or low-input magazines or books	−1.92	−3.86	<.0001

to bridge the gap between the farming population and the public concerned with agricultural pollution. They appear to want to minimize harmful environmental effects and are not just choosing practices based on economics or public pressure to reduce pesticides. One possible choice related to use of agricultural chemicals in the questionnaire was "whether my customers prefer that I use or don't use the product." Although 56 percent of the alternative farmers indicated this is very important and another 35 percent said it was somewhat important, this factor was ranked twelfth in overall importance, far behind health risks or environmental degradation.

Similar strong concerns about health risks have been found in almost all studies of alternative farmers that assessed motivations for reducing or quitting syn thetic chemical use (Wernick and Lock eretz, 1977; Data Probe, 1988; Malia an Korsching, 1989; Lasley et al., 1990 Concerns about groundwater qualit and agricultural pollution, which ar closely linked to personal and famil health, are also important (Madder 1988; Buttel et al., 1990). Soil qualit and erosion tend to be highly ranke among concerns of most alternativ farmers (USDA, 1980; Blobaum, 198 Lockeretz and Madden, 1987; Madder 1988). General environmental benefit also motivate many of these farmer (USDA, 1980; Data Probe, 1988; Mali and Korsching, 1989). Alternative farm ers in this study unanimously reporte that environmental concerns (ground water quality, soil quality, air quality and effects on birds and other wildlife were either somewhat or very important

Simultaneous comparison of socioeconomic and farm characteristics, information sources, and concerns

Logistic regressions showed how each variable affected the probability of a farmer being in the alternative grou compared to the full-time conventiona or part-time conventional group. The first model included socioeconomic farm, and information-source variables most commonly used to predict whethe farmers adopt conservation measures Variables that significantly ($p < .05$) dis criminated between alternative and full time conventional farmers were that al ternative farmers more frequently reac literature promoting reduced-chemica farming, own more of the land they oper ate, earn less farm income, and have les farming experience (Table 6). Only in formation sources (reading reduced chemical literature more frequently) sig nificantly discriminated alternative fron part-time conventional farmers. In othe words, information sources distin guished alternative from both types o conventional farmers better than the so cioeconomic or farm factors included i this model, and no other farm character istics enhanced the ability of these fou variables to predict which managemen strategy a given farmer uses.

I selected three concerns about agricultural chemicals to add to the first model so that I could test whether their addition significantly improved the ability of the model to predict whether a farmer was in the alternative group. In stepwise logistic regressions with concerns alone, the concerns best distinguishing alternative farmers from part-time or full-time conventional farmers were cost of the product, possible effects on birds and other wildlife, and whether the extension agent recommended the product. The addition of other concerns about farm chemicals did not significantly improve the ability of this group of variables to predict whether farmers are in the alternative group or not. The last of the three concerns refers to an information source but also reflects a farmer's acceptance of conventional practices and values, which include standard chemical use and a profit-maximizing approach to farming.

Adding these three concerns about farm chemicals to the first model significantly ($p < .005$) improved its capacity to predict the group to which farmers belong. In this full model, alternative and full-time conventional farmers differed significantly in that alternative farmers rank their extension agents' recommendations about farm chemicals lower, earn lower farm incomes, more frequently read books or magazines promoting reduced-chemical farming, own more of the land they work, rank cost lower among their concerns about chemical products, and have less farming experience (Table 7). Compared to part-time conventional farmers, alternative farmers more frequently read books or magazines promoting reduced chemical inputs, rank their extension agents' recommendations lower and rank possible effects of chemical products on birds and other wildlife higher among their concerns, and have less farming experience.

Discussion

Information sources, including whether the extension agent's advice is highly valued, were the best predictors overall of the management strategy a farmer used. Results reported above highlight the sharp differences in information sources and concerns about farm chemicals between farmers who already use alternative practices and those who do not. Interviewed farmers frequently said that exposure to friends, books, or magazines promoting organic or reduced-input methods catalyzed their decision to move away from conventional farming. But why does this spark catch fire in just some farmers and not others? Socialization and especially exposure to the world outside the family farm were highly associated with choosing alternatives to conventional chemical use. Alternative farmers were less likely to have grown up on farms than conventional farmers, had higher educational levels (generally at least a college degree in a non-agricultural discipline), and had traveled and worked in non-farming occupations more often. They also had less farm experience and were less likely to operate the farm where they grew up. They may have been more willing to consider non-conventional farm strategies because they have less invested, materially and emotionally, in conventional farming. They have been less thoroughly trained in conventional methods, and breaking out of a traditional farming style does not violate family or community traditions that bind other farmers. Their education and experiences may lead them to be less cautious in general, in the sense of being willing to try new practices. Yet their information-seeking patterns showed another kind of caution. The alternative farmers I surveyed depended heavily on sources biased toward organic farming, and farmers I met during interviews and study of advocacy organizations often were unwilling to look beyond the practices they considered acceptable, even when they had not decided themselves which practices should be excluded. That is, they had traded one set of proscriptions (implicit in guidelines created by traditional agricultural institutions) for another set decided by some organization outside the mainstream.

Information sources of North Carolina alternative farmers raise several issues for farmer education. This study found that alternative farmers do not use the Extension Service much, presumably because they think it does not provide adequate information and technical assistance on substitutes for synthetic chemicals. There was a marked polarity in farmers' relations to the Extension Service. Those using conventional methods rely heavily on this service, while those who use alternative methods seldom reported that extension agents are helpful. They not only reported indiffer-

Table 7. Logistic Regression of Group to which Farmer Belongs on Farm Income, Farming Experience, Tenancy, Information Source, and Concerns ($n = 141$).

Full-time conventional farmers contrasted with alternative farmers:

Parameter	Coefficient	t-Statistic	p
Farm income	1.36	3.38	.0005
Farming experience	1.27	2.16	.016
Proportion owned to rented land	−.97	−2.93	.002
Whether farmer frequently reads organic or low-input magazines or books	−2.34	−2.90	.002
Importance of cost of product	1.85	2.53	.006
Importance of possible effects on birds and other wildlife	−1.91	−1.50	.068
Importance of extension agent's recommendation	1.96	3.68	.0002

Part-time conventional farmers contrasted with alternative farmers:

Parameter	Coefficient	t-Statistic	p
Farm income	.20	−.25	.402
Farming experience	.69	1.87	.032
Proportion owned to rented land	−.08	−.32	.379
Whether farmer frequently reads organic or low-input magazines or books	−1.53	−2.71	.004
Importance of cost of product	.40	.79	.221
Importance of possible effects on birds and other wildlife	−2.37	−2.05	.021
Importance of extension agent's recommendation	.93	2.49	.007

ence or ignorance: alternative farmers frequently and stridently criticized extension agents' prejudices against organic farming. Yet many North Carolina agents with whom I met and spoke while conducting this study seem sincerely interested in alternatives to intensive chemical use and are frustrated by lack of reliable technical information they might give farmers. The inadequate support of alternative practices and the poor rapport between alternative farmers and extension agents are important because alternatives to synthetic chemicals are sought and used by more than just a small group of farmers with low farm incomes. Data I collected on farmers' preferences for alternatives to synthetic chemicals showed that most farmers, not only those already avoiding synthetic chemicals, would prefer to use such practices if profits were not adversely affected.

Many people in North Carolina state government and agricultural research, teaching, and extension institutions are genuinely trying to address health and environmental problems of agriculture. Advocates of alternative agriculture would benefit from closer alliances with these people and institutions. Without these ties, alternative farming supporters lack resources and risk estrangement from conventional farmers, whether part-time or full-time, who trust these institutions. The most likely point of contention between traditional extension networks and alternative farming advocates is economic security versus environmental safety. The importance that alternative farmers and their advocates attribute to environmental problems may lead them to discount the economic risks and costs that alternative practices impose on farmers.

The dominant concerns of alternative farmers in North Carolina overlap little with conventional farmers' concerns. Alternative farmers appear to value environmental benefits more than financial benefits. In effect, they are willing to pay in lost farm income for the public good. There is considerable evidence that farmers as a group will forego substantial economic rewards to preserve their farm lifestyle (Barlett, 1986); but alternative farmers are also paying to preserve public resources of soil and clean water. Perhaps they can afford to do so more than full-time conventional farmers partly because they have higher off-farm incomes. Yet part-time conventional farmers derive an even greater proportion of their incomes from off-farm sources than alternative farmers but are not very concerned about adverse environmental effects of farm practices on society.

Potential adopters of reduced-chemical farming practices in North Carolina (that is, all farmers not already using these practices) are heterogeneous in their concerns and constraints. Different educational tactics are needed to promote reduced-chemical methods to the two groups identified in this study, and perhaps these groups should be subdivided further. In addition, the rationale for reduced-chemical farming needs to be different for potential adopters and potential supporters (legislative bodies and the public). Environmental benefits must be quantified to justify public support of programs designed to promote alternative farming. But such benefits will not be sufficiently compelling to persuade most farmers using conventional chemicals to change their practices. This study has shown that conventional farmers are more likely to be convinced of the merits of reduced-chemical pest control and fertilization techniques by demonstrations of their health benefits and negligible associated losses of profitability than by their environmental advantages.

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Energy, water, and economic savings of improved production systems on the Texas High Plains

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Abstract. *The purpose of this paper was to quantify economic and energy use implications of new improved irrigation and limited tillage production systems for the Texas High Plains. Per hectare uses of natural gas and electricity under alternative irrigation distribution systems for corn, sorghum, wheat, cotton, and soybeans were utilized to estimate total amounts of natural gas and electricity used in the production of these crops on the High Plains of Texas. The amount of diesel fuel used was estimated for conventional and limited tillage systems under dryland and irrigation production. Total amounts of water used for the five crops under the improved and conventional irrigation systems were also estimated for the High Plains. Results indicated improved irrigation and limited tillage systems reduced energy and water use on the High Plains. Total natural gas and electricity were estimated to decline over 20 percent, diesel fuel declined 32 percent, and water use for irrigation declined about 23 percent. Use of the improved irrigation and limited tillage production systems was also shown to significantly increase annual net returns to farmers ($40.0 million or 13.3 percent).*

Key words: improved and conventional irrigation systems, irrigation water, limited tillage, economic impact, Texas High Plains, profit, natural gas, electricity, diesel fuel

Introduction

Crop production throughout the Great Plains of the United States relies heavily upon irrigation from the Ogallala. In addition, conventional tillage practices use large quantities of diesel fuel. These two factors make farming in this part of the United States energy intensive. Farmers' production goal was, when fuel was inexpensive and costs of production were low, to maximize crop yields without much regard to energy use, water use efficiency, or amount of purchased nutrients and chemicals required. But in response to increasing costs of production (particularly energy related) and concern for the environment, alternative technologies that included new energy efficient systems of production were developed (Clarke, 1980). In this study, changes in irrigation and tillage fuel use associated with improved irrigation systems and limited tillage practices are quantified. The study was done for the Texas High Plains, but the results have strong implications for pump irrigated regions across the U.S. Although not included in this study, improved efficiency of distributing irrigation water reduces percolation of nutrients and chemicals below the soil profile, which is often associated with a reduction in application of purchased nutrients (Sweeten and Jordan, 1987).

Production agriculture in Texas accounts for over 8 percent of the total energy use in the state, while directly or indirectly producing over 24 percent of the gross state product, second only to the energy sector (Clarke, 1980). The majority of energy is used for crop production, with about 37 percent of all agricultural energy use going to pumping and distributing irrigation water (Clarke, 1980). About 3.64 million hectares of land are irrigated in Texas. The Ogallala Aquifer underlies the Texas High Plains and is the water source for 1.9 million irrigated hectares (Sweeten and Jordan, 1987). An estimated 937 to 2,807 liters of gasoline equivalents are used on each irrigated hectare with natural gas being the principal fuel used (Kelly, 1977). In 1982, about 27,641 GJ of natural gas were used for crop production, compared to 156.0 million liters of gasoline, 255.5 million liters of diesel, and 571 million kwhs of electricity in a 40-county area of the Texas High Plains (U.S. Department of Commerce, 1984). Irrigation costs constitute over one-third of total production costs for the major irrigated crops produced on the Texas High Plains (Hall et al., 1988).

Increased pumping lifts and unit energy costs and decreased well yields over the years have affected farmer profit and contributed to a gradual decline in irrigated area and irrigation water use per hectare (Sweeten and Jordan, 1987). Of particular significance was the rise in energy costs for pumping. The cost of energy for pumping increased about fourfold at its peak in the early 1970s (Ellis et al., 1985b). Although energy costs declined slightly from their peak and are stable in recent years, the resulting increase in the total cost of crop production is of utmost importance because it

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renders irrigated agriculture more vulnerable to energy price increases than non-irrigated agriculture. Farmers in the Texas High Plains have expressed their concern about the economic feasibility of continued pump irrigation and are exploring opportunities to improve irrigation and pumping plant efficiency.

Recently, several new irrigation systems have been developed or improved that are technically more efficient in energy and water use. Although developments of the new irrigation techniques could increase on-farm irrigation application efficiency and reduce energy requirements, it is not clear which technique or combination of techniques are/ will be the most economical from the producer's standpoint. Crop prices relative to energy prices and capital costs and available water supplies are critical in determining the economic feasibility of upgrading an irrigation system or replacing one system with another (Lee et al., 1985). Producers may continue to irrigate with their current systems as long as the variable operating costs are covered but might convert to dryland production rather than replace the irrigation system when the useful life of the current system has expired.

In addition, adoption of limited or minimum tillage systems is rapidly expanding in the Texas High Plains. Limited tillage systems generally decrease soil erosion, fuel, labor, and machinery costs and increase soil water storage and yields as compared to the same under conventional tillage systems (Sweeten and Jordan, 1987). The purpose of this paper is to explicitly calculate the energy, irrigation water use, and farmer profit implications of new irrigation systems, including the low energy precision application (LEPA) system and improved furrow, and limited tillage systems on the Texas High Plains.

Study area

The study area included 40 counties of the Texas High Plains, which is a relatively flat semi-arid region located on the southern Great Plains. The hardlands, which are composed of fine-textured clay and clay loam soils, comprise 54 percent of the total area and 40 percent of the irrigated soils. The remaining 46 percent of the area is split about evenly between the mixed lands, composed of medium-textured loams and loamy sands, and the sandy lands, composed of coarse-textured sands (Godfrey et al., 1967). These soils are capable of high yields; but their productivity is limited by low rainfall, high winds, temperature extremes, and a short growing season. Average annual rainfall ranges from 36 to 53 cm, with the growing season averaging from 180 to 220 days.

The High Plains of Texas accounts for over 1/3 of the total crop land, nearly 2/3 of the irrigated land, and almost 1/3 of the agricultural income in the state (Clarke, 1986). Crop production, including government payments, accounts for 58 percent of the cash receipts from agriculture in the region, with livestock accounting for 42 percent in 1982 (U.S. Department of Commerce, 1984). Corn, grain sorghum, cotton, soybeans, and wheat are the most common annual crops grown. In 1985, crop and livestock cash receipts from 31 of the heavily irrigated counties totaled $2.9 billion, which was almost 30 percent of the state total. There has been a 250 percent increase in agricultural cash receipts in those 31 counties since 1970 (Lansford et al., 1987).

Irrigation and tillage systems

Pumping irrigation water is a major energy user of Texas High Plains agriculture and constitutes a large portion of the variable cost for irrigated crops. The main conventional irrigation systems used on the High Plains are furrow irrigation installed mainly on "hardland" soils and sprinkler systems on "mixed" or "sandy" soils.

Furrow irrigation accounted for 63 percent of the irrigated land in the Texas High Plains in 1984. Nevertheless, irrigation crop area decreased 33 percent from 1974 to 1989. Conventional graded furrow irrigation is often inefficient due to losses by tailwater runoff, deep percolation, and evaporation. Preplant irrigations are usually regarded as the most inefficient due to some soils' deep percolation losses in the preseason (Sweeten and Jordan, 1987). Several techniques are being or have been designed to increase energy and water use efficiency while reutilizing the capital-cost economy of furrow irrigation. Tailwater losses can be reduced by shortening the application time or installing tailwater recovery systems. The research has shown this practice resulted in 13 percent to 28 percent increases in irrigation water use efficiency (Sweeten and Jordan, 1987).

Timely application of alternate furrow irrigation improves lateral water movement in the soil and reduces deep percolation losses, thus allowing more area to be irrigated (Ellis et al., 1985a). Alternative row furrow irrigation lowers the water intake by an average of 30 percent for sorghum and 20 percent for vegetables, while it lowers yields by 2-11 percent. Alternate row furrow irrigation is satisfactory with narrow row spacings on slowly permeable soils or perhaps with conventional 102 cm row spacings on moderately permeable soils (Sweeten and Jordan, 1987). Alternate furrow can also be used with furrow diking or row dams in the non-irrigated furrows to reduce rainfall runoff. Significant yield increases for both cotton and grain sorghum have been obtained via this practice (Lyle and Dixon, 1977; Ellis et al., 1985b).

Agronomic and agricultural engineering research have directed considerable attention for development of minimum and no-tillage production systems. The major underlying issue is to reduce energy and water requirements whereby net returns remain the same or tend to rise above conventional methods. Minimum tillage, in which a portion of residue from the previous crop is left on the soil surface, can influence furrow irrigation in several ways. On the one hand, the crop residue can enhance soil storage of precipitation by lessening soil compaction due to raindrop impact and wheel traffic while lowering the evaporation rate. The increased soil moisture may reduce irrigation water intake. On the contrary, residue can retard furrow stream advance and increase water intake. Research on the Texas High Plains has attempted to balance these factors for improved irrigation water manage-

ment and for optimizing crop production under a variety of crop rotations and reduced tillage methods. Minimum and no tillage with graded furrow irrigation has increased irrigation water use efficiencies in wheat and sorghum by about one-third. Yields were increased by approximately 10 percent (Sweeten and Jordan, 1987).

Sprinkler systems are used by farmers on 37 percent of the irrigated land on the Texas High Plains (Sweeten and Jordan, 1987). The objective of sprinkler irrigation is to uniformly apply water over the field for crop use at a rate that is lower than the soil intake rate to prevent surface runoff (Herman and Kohl, 1983). The application uniformity depends on sprinkler spacing, operating pressure, nozzle dynamics, travel speed and path, wind and evaporation (Sweeten and Jordan, 1987). Both stationary--solid set and periodic lateral move, and moving or spraying--center pivot, traveling gun and traveling lateral, types of sprinkler systems are used. However, a growing number of hectares have been put under pivot systems that utilize high pressure sprinkler nozzles, low pressure spray nozzles, or more advanced LEPA nozzles. Distribution uniformity, affected by wind and evaporation, and runoff are major factors in design and operation of sprinkler systems. For sprinkler systems, we used low pressure systems as the base.

Center pivots are capable of supplying frequent, relatively light irrigations (as compared to furrow irrigation). Average irrigation system efficiencies of 71 percent and 64 percent were obtained with high and low pressure center pivots, respectively, at Etter and Bushland, Texas. These values were higher than others determined by USDA-SCS in field evaluations. Runoff was reduced from both high pressure (impact) and low pressure (spray) nozzles when conventional tillage was supplemented by deep plowing or furrow diking or was replaced by minimum tillage (Sweeten and Jordan, 1987).

The LEPA system has been developed on the High Plains to distribute water at very low pressure of less than 40 kPa at a height of less than 0.3 m above the surface using drop tubes from moving overhead lateral pipelines. Orifice-controlled emitters supply water to only one furrow, so instantaneous application rates are high. Therefore, furrow dikes are a recommended component of the system as they greatly reduce runoff both from irrigation water and rainfall in experiments. Average values of application efficiency with furrow dikes and distribution uniformity are 99 percent and 96 percent, respectively, which indicates a system efficiency of 95 percent. The LEPA irrigation system consistently provided higher irrigation efficiency than furrow and center pivot systems. It also improved crop yield and irrigation water use efficiency and lowered the energy requirement (Sweeten and Jordan, 1987). LEPA investment costs are approximately $692 and $605 per hectare respectively, for purchase of every row and alternate row systems. Cost to convert from a low pressure sprinkler system to LEPA was estimated at $178.0 per hectare (Hall et al., 1988).

Methods

Aquifer characteristics

The Texas High Plains has developed into a highly productive agricultural region based largely on irrigation water pumping from the Ogallala Aquifer. This aquifer runs beneath much of the Great Plains from Southern South Dakota to a few miles north of the Pecos River in Texas. The Ogallala underlies about 90,000 km^2 of the Texas High Plains and was estimated to hold 493 km^3 of water in storage (Knowles, 1984). Over 70,000 irrigation wells have been completed into the Texas portion of aquifer, which also serves as the municipal water supply for many towns and most rural residents. Well yields are commonly 6.3 liters per second to 31.6 liters per second (Schefter, 1984). Irrigation accounts for 95 percent of the total water use (Knowles, 1984). Irrigation water withdrawal from the Ogallala Aquifer in Texas is currently about 6.2 km^3 per year (Sweeten and Jordan, 1987).

The Ogallala Aquifer underlies essentially all the crop land on the Texas High Plains. However, saturated thickness of the High Plains Ogallala Aquifer in Texas ranges from less than 30 m to more than 91 m (Texas Water Development Board, 1986). Regarding depth to water table, 30 percent of the water is within 30 m of the surface and 81 percent is within 122 m (Sweeten and Jordan, 1987). Approximately 1.5 million hectares in the southern part of the Texas High Plains and 105.2 thousand hectares in the northern portion have a saturated thickness less than 30 m. Much of this crop land is produced dry land. For those hectares that were once irrigated, the conversion to dry land is principally on the southern area due to limited ground water (Ellis et al., 1985a).

Natural recharge rates to the Ogallala Aquifer have been estimated at only 0.5 cm per year or 0.46 km^3, which is substantially less than current withdrawal rates. Ground water in the Ogallala Aquifer is of excellent quality for irrigation purposes, which makes limited irrigation feasible and leaching for salinity control unnecessary. Consequently, water conservation practices have been and should continue to be strongly encouraged for both short- and long-term economic benefit (Sweeten and Jordan, 1987).

Irrigation on the High Plains developed slowly, beginning in 1911 (Texas Water Development Board, 1986). The drought of the 1950s, coupled with the availability of improved pumping equipment, brought a more rapid increase in the use of irrigation. The acceleration of developing irrigation continued from 1958 to 1969, when estimated well numbers increased from 43,000 to 63,000 (Texas Water Development Board, 1986). The number of irrigation wells on the Texas High Plains is approximately 77,000, 59 percent powered by natural gas, 38 percent by electricity, and 3 percent diesel driven. The number of irrigated hectares increased until 1976 and then began to decline. Major reasons for the decline in the number of hectares irrigated are: higher irrigation costs, increased demand on the underground water resources, and declining commodity prices (Lansford et al., 1987). These factors emphasize the importance of irrigation decisions on the High Plains.

Computer model

A user-oriented computer model de-

veloped in the Department of Agricultural Economics at Texas A&M University was modified to calculate natural gas and electricity use of alternative irrigation distribution systems (Hall et al., 1988). This model was then applied to simulate the economic implications and associated energy use for alternative irrigation distribution systems. The computer model uses information about a distribution and crops system, such as crop yield, water use, operating pressure, irrigation system investment cost, well and pump characteristics, crop prices, and variable and fixed costs of production. Data on crop yield, water application, irrigation labor, crop price and variable and fixed costs were taken from published 1988 crop enterprise budgets of the Texas Agricultural Extension Service (Extension Economists-Management, 1988).

Data on irrigation system investments are shown in Table 1. The irrigation system investment estimates are in 1988 dollars. The irrigation system investments were converted to an annual basis by amortizing over the life of the system (assumed to be 15 years) at an 8 percent interest rate.

Key assumptions concerning delivery efficiencies and operating pressures for the four irrigation systems are presented in Table 2. It was assumed that improved furrow practices used tailwater pits, recirculation pumps, reduced length furrows, and significantly improved levels of management. Furrow diking accompanied the use of LEPA systems (Ellis et al., 1985a). Based on reports by Lacewell (1989), Victurine et al. (1985), and Laughlin et al. (1980), cost to construct a pit and investment in pipe and an electric engine was estimated to be $11,238 for each 121.5 hectares of irrigated crop land. Based on life of each component of the system at 8 percent discount rate, an average annual fixed cost per hectare of irrigated land of $10.8 was estimated for tailwater recovery systems.

The well yield corresponding to the reduced water-bearing sand is given by Hughes and Harman (1969):

$$Y_t = Y_0 \text{ if } T_t/T_0 \geq 0.83667 \quad (1)$$

else

$$Y_t = 1.14 \cdot (T_t/T_0)^{0.71} \cdot Y_0 \quad (2)$$

where

Y_t = well yield in liters per second (lps) in the current year;

Y_0 = original well yield in liters per second is assumed to be 50.48 lps for this analysis;

T_0 = original saturated thickness of the aquifer is assumed to be 76.2 meters;

T_t = saturated thickness of the aquifer in the current year.

With original well yield set at 50.48 lps and original saturated thickness set at 76.2 meters, well yield for any situation is a maximum of 50.48 lps and is maintained to a saturated thickness of 63.70 meters, after which the well yield declines according to equation (2). Although potential well yield of the aquifer is much greater, this relationship approximates the typical well for the Texas High Plains (Hughes and Harman, 1969; Petty et al., 1979).

For the analysis, the region was divided into two areas and average saturated thickness and lift for irrigation wells estimated for each area (Masud and Lacewell, 1989). Based on saturated thickness, well yield was calculated. Well yield, lift, pump and distribution system efficiency were used to calculate cost of irrigation water for each scenario. Output from the computer model includes gross receipts, variable costs, net returns above variable costs, irrigation costs, and amount of natural gas and electricity used per hectare by crops for each irrigation system.

Other data

Farming practices, cropping patterns, and irrigation vary across the Texas High Plains. To capture, in part, some of this variation, the region was divided into two areas and then further divided into two levels of saturated thickness for each area. Data were obtained on each of the regions separately to reflect differences in energy use as well as other inputs. Per hectare diesel use for dryland and irrigation on crops using conventional and limited tillage methods are presented in Table 3. This per hectare information was then multiplied by the number of hectares devoted to each crop in each of the two areas to get total diesel fuel use by crops in the region. In this study, other inputs such as labor, seed, herbicides, and machinery (variable cost) for the limited tillage systems were not estimated.

Total irrigated land for corn, sorghum, wheat, cotton, and soybeans for each area of the High Plains of Texas were taken from Texas Water Development Board (1986). Sprinkler and furrow irrigation land for corn, sorghum, wheat, cotton, and soybeans were estimated from Masud and Lacewell (1989). Water use per hectare, by area, for conventional sprinkler and furrow irrigation systems were taken from Extension Economists-Management (1988) and were utilized to calculate per hectare crop water use for LEPA and improved furrow by relating to the water delivery efficiencies (Masud and Lacewell, 1989). Crop water use by irrigation system in each area was estimated by multiplying

Table 1. Irrigation Distribution Systems Investment.

Irrigation Systems	Investment ($/ha)
Sprinkler[a]	
Conventional	507
LEPA	685
Furrow	
Conventional[b]	232
Improved[c]	251

[a] Hall et al. (1988).
[b] Petty et al. (1979).
[c] Includes tailwater return pit, electric engine and pipe estimated from Lacewell (1989), Victurine et al. (1985), and Laughlin et al. (1980).

Table 2. Irrigation Distribution Systems Pressure and Delivery Efficiency.

Item	Unit	Sprinkler Irrigation		Furrow Irrigation	
		Conventional	LEPA	Conventional	Improved
Required pressure	kPa	310.5	41.4	34.5	34.5
Delivery efficiency	%	80	92	69	80

Sources: Lyle and Bordovsky (1980), and Lyle et al. (1981).

Table 3. Diesel Use Per Hectare for the Conventional and Limited Tillage Systems by Crop and Irrigation and Dryland, Texas High Plains.[a]

Crop	Conventional Tillage		Limited Tillage	
	Irrigation	Dryland	Irrigation	Dryland
	liters per hectare			
Corn	119.3	—[b]	90.3	—[b]
Sorghum	192.8	88.6	133.0	53.2
Wheat	81.8	76.6	56.4	52.8
Cotton	136.8	132.3	100.1	79.8
Soybeans	120.2	—[b]	82.9	—[b]

[a] Price of diesel varies across the Texas High Plains. To capture, in part, some of the variation, diesel prices per liter in the Northern and Southern High Plains were assumed to be $0.18 and $0.22, respectively.
[b] Corn and soybeans are not raised dryland.
Source: Ellis et al. (1985a).

total amount of crop by the amount of water used with each irrigation system. The amount of crop land irrigated by natural gas and electricity was derived from Sloggett (1982), and the allocation of each of these fuels to sprinkler and furrow systems by crop and by area is presented in Masud and Lacewell (1989).

Estimated natural gas and electricity use, assuming conversion of sprinkler and furrow irrigated land to LEPA and improved furrow, was obtained by multiplying their respective values of natural gas and electricity use per hectare by the amount of each crop in each area.

In addition, the amount of natural gas, electricity, water, and diesel use, as well as net returns for the conventional and new improved irrigation systems, were aggregated across the Texas High Plains to estimate the benefit of the improved irrigation systems. Economic implications for the region were based on increased net returns for irrigated land and reduced diesel costs on all irrigated and dry land assuming a limited tillage system. The limited tillage system assumes (i) use of implements other than the moldboard plow, (ii) crop residues left on the soil surface to mitigate erosion and to help retain moisture, and (iii) weed control accomplished primarily by use of herbicides (Office of Technology Assessment, 1982). Limited tillage system was assumed both for irrigation and dry land crops. In a limited tillage system, diesel is the principal fuel used and, hence, savings in diesel use for limited tillage system were estimated for irrigation and dry land, as compared to diesel use for conventional tillage system, for irrigation and dry land.

Results

Conditions under the conventional irrigation and tillage systems refer to those that existed in the early 1980s. Approximately 25 percent of the land was tilled under a limited tillage system (Ellis et al., 1985a). Irrigation efficiency ranged from 60 to 70 percent (Wyatt, 1978-81). All sprinkler irrigation for the typical system was assumed to be under low pressure (310.5 kPa) with a distribution efficiency of 80 percent. A 69 percent efficiency was used for the typical furrow system (Ellis et al., 1985a). During the 1980s, adoption of many of the improvements evaluated began, hence this work includes some of these benefits. Cropping patterns and hectares of sprinkler and furrow irrigation were for 1984 (Texas Water Development Board, 1986). Thirty-six percent of irrigated acres involved sprinkler systems.

To evaluate economic and energy used implications of improved irrigation distribution systems and to compare with the conventional irrigation systems in the Texas High Plains, output from the computer model was utilized to quantify natural gas and electricity use for irrigation, by crop. Implications of improved irrigation systems on water use per hectare were based on results presented by Ellis et al. (1985a). Estimates of diesel fuel use per hectare were derived from Ellis et al. (1985a) for conventional and limited tillage production practices by crop and irrigation versus dry land. The economic impact of improved irrigation systems relative to conventional systems was estimated separately for natural gas powered pumps and electricity powered pumps and by crop. Last, the implications for the region were developed by aggregating across the Northern and Southern High Plains of Texas. The results presented herein are those which would be obtained if all producers adopted limited tillage and improved irrigation systems.

Energy use

Total amounts of natural gas and electricity used in crop production under the improved furrow and LEPA irrigation systems, in comparison with the conventional furrow and sprinkler irrigation systems on the Texas High Plains, are presented in Table 4. Across the region, there were savings in natural gas and electricity use for the improved irrigation systems due to lower pressure requirements and greater distribution efficiency of these systems. Total natural gas use on the Texas High Plains under the improved irrigation systems was 17,844 GJ. When compared with the conventional irrigation systems, natural gas savings of 20.2 percent were realized. About 463.1 mWh of electricity would be used under the improved irrigation systems. The improved irrigation systems indicated electricity savings of 20.3 percent as compared to the conventional irriga-

Table 4. A Comparison of Natural Gas, Electricity, and Water Use in Crop Production under Alternative Irrigation Systems, Texas High Plains.

Item	Unit	Conventional Irrigation			Improved Irrigation			Energy, Water Savings
		Sprinkler	Furrow	Total	LEPA	Furrow	Total	
Natural gas	GJ	6,521	15,845	22,366	4,161	13,683	17,844	4,522
Electricity	mWh	167.3	413.8	581.1	106.9	356.2	463.1	118.0
Water Appl.	km^3	1.61	4.96	6.57	1.40	3.67	5.07	1.50

See Masud and Lacewell (1989) for areas, water applied, and energy use by crops.

tion systems (Table 4).

Total diesel fuel used in tillage operations for irrigation and dry land crop production under the conventional and limited tillage crop production practices is shown in Table 5. Reduced water and machinery requirements, due to limited tillage, promote greater savings in diesel fuel use in the region. Limited tillage practices for dry land production reduced diesel use more than for irrigated production. Total estimated diesel fuel use savings attributable to limited tillage was 108.9 million liters or 32.1 percent.

Water use

Given the increased delivery efficiency of the improved irrigation systems, there is an opportunity for substantial water savings with the adoption of LEPA and improved furrow irrigation systems. Assuming constant cropping patterns and yield levels, total water use for LEPA and improved furrow was found to be 5.07 km^3 for the Texas High Plains or a savings of 22.8 percent as compared to conventional irrigation systems (Table 4).

Economic impact

New irrigation systems such as LEPA and improved furrow increase on-farm irrigation application efficiency and reduce energy and water requirements in comparison with conventional irrigation systems (Hall et al., 1988). For adoption to occur, it is expected that net returns to land, management, and risk would need to be at least as great with a new technology as those available under conventional means (Ellis et al., 1985b). Estimated annual returns over variable costs for natural gas and electricity and costs for diesel fuels on the High Plains are presented in Table 6. LEPA and improved furrow irrigation systems powered by natural gas and electricity showed an increase in net returns compared to conventional systems. The use of LEPA and improved furrow irrigation systems increased net returns by $15.1 million for natural gas powered wells and $6.4 million for electricity powered wells as compared to conventional irrigation. Cost of diesel fuels used for limited tillage was $23.2 million lower than the conventional tillage system or a fuel cost savings of about 32.2 percent.

The results presented in Tables 4, 5, and 6 indicate that the improved systems would have positive economic benefits for the farmers in the area as well as reduce use of purchased inputs. Adoption of the improved irrigation systems would reduce use of natural gas, electricity, water, and diesel about 20.2, 20.3, 22.8, and 32.1 percent, respectively. Net benefits to the improved irrigation and limited tillage systems on all hectares would be $44.7 million annually, which is a 14.9 percent increase over conventional irrigation and tillage systems. Limited tillage system accounted for $23.2 million of the increased net returns, and improved irrigation systems contributed $21.5 million to increased net returns. Discounting the increased net returns of $44.7 million at 8 percent over 15 years results in an estimated present value of benefits to limited tillage and improved irrigation systems of $382.6 million.

Conclusions

Declining ground water levels, increased energy, and other input costs are important in the development and adoption of improved irrigation systems, such as LEPA and improved furrow in the Texas High Plains as well as across the western United States. In this study, economic and energy use impacts of im-

Table 5. A Comparison of Diesel Fuel Use for Alternative Tillage Systems on Irrigation and Dryland Crops, Texas High Plains.

Item	Irrigated Cropland	Dryland Cropland	Total
	million liters		
Conventional tillage	190.8	148.6	339.4
Limited tillage	136.9	93.6	230.5
Diesel savings:	53.9	55.0	108.9

See Masud and Lacewell (1989) for areas and diesel use by crop.

Table 6. Estimated Impact on Farmer Profit Attributable to Limited Tillage and Improved Irrigation Systems, Texas High Plains.

	Conventional Systems				Improved Systems				
Item	Sprinkler Irrigation	Furrow Irrigation	Conv. Tillage	Total	LEPA Irrigation	Furrow Irrigation	Limited Tillage	Total	Benefit
	million$								
Net returns[a]									
Natural gas[a]	90.9	196.5	—	287.4	98.7	203.8	—	302.5	15.1
Electricity[a]	27.3	57.5	—	84.8	31.2	60.0	—	91.2	6.4
Cost									
Diesel[b]	—	72.1	72.1	—	—	—	48.9	48.9	23.2
Total	118.2	254.0	72.1	300.1[c]	129.9	263.8	48.9	344.8[c]	44.7[d]

[a] Annual net returns on irrigated land are returns above variable costs and annual fixed costs of the distribution systems.
[b] Annual cost for irrigated and dryland, comparing conventional tillage to limited tillage systems.
[c] Based on increased net returns on irrigated land and reduced diesel costs on all hectares of cropland.
[d] When the increased net returns are discounted at 8% over 15 years, the present value of benefits to limited tillage and improved irrigation systems results in an estimated $382.65 million.

proved irrigation and limited tillage systems in the High Plains of Texas were evaluated. A user-oriented computer model developed in the Department of Agricultural Economics, Texas A&M University, was modified to estimate per hectare use of natural gas and electricity under alternative irrigation distribution systems for crop production in the Texas High Plains. These per hectare estimates of energy use were utilized to calculate total amounts of natural gas and electricity used in the production of crops under the improved and conventional irrigation systems. Per hectare diesel fuels used for crops for conventional and limited tillage systems for irrigation and dry land were estimated from secondary sources and were used for estimating the total amount of diesel fuel used. Total amounts of water used for crops under the improved and conventional irrigation systems on the High Plains were also calculated from per hectare estimates. Based on constant cropping patterns and yield levels, this analysis indicates adoption of improved irrigation and limited tillage systems would reduce energy and water use on the High Plains of Texas. Use of the improved irrigation and limited tillage systems would lower cost of energy and water in crop production and significantly increase net returns to farmers. For example, net benefits to the improved irrigation and limited tillage systems on all hectares were an estimated $44.7 million annually, which was a 14.9 percent increase over conventional systems. Discounting the increased net returns of $44.7 million at 8 percent over 15 years resulted in an estimated present value of benefits to improved irrigation and limited tillage systems of $382.6 million.

Study limitations include a need for more current data on hectares of land devoted to conventional and improved irrigation systems by crops. Also in the analysis, a single set of yield and input and output prices was assumed. Finally, costs of capital and returns over capital costs were not estimated in this study. However, these analyses include reported cropping patterns and energy used by farming systems which result in reasonable estimates of aggregate benefits attributable to adoption of minimum tillage practices and improved irrigation systems.

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Policies, programs, and regulations to support the transition to sustainable agriculture in Canada

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Abstract. *The development of political strategies in Canada to support the transition from conventional to sustainable agriculture has been limited by the absence of a comprehensive conceptual framework for identifying the most critical policies, programs, and regulations. In this paper, we propose a framework that uses an efficiency/substitution/redesign spectrum to categorize both sustainable farming systems and government activities. The framework is then used to identify a diverse range of short, medium, and long-term strategies to be pursued by governments in Canada to support the transition. Strategies discussed include research, diffusion, and training; market development; and safety net programs and tax provisions. Finally, the implications and implementation of the redesign concept for food production, processing, and distribution are outlined.*

Key words: sustainable agriculture, policy, transition, research, training, regulation

Introduction

The Canadian food and agriculture system is in transition to a more sustainable approach to food production, processing, and distribution. Indications that the transition is already under way include the increasing number of farmers experimenting with new techniques or actually converting their farms, the growing availability of products of sustainable approaches in the marketplace (particularly organic food), and heightened public awareness of environmental problems associated with agricultural production.

The institutions involved in supporting the food and agriculture system (e.g., universities, credit agencies, governments, extension services) have already made significant contributions to sustainability in our agriculture system. Financial assistance, IPM programs, varietal developments, and research on biorational products and soil conservation systems have all contributed to progress in achieving a sustainable agriculture. However, it is widely recognized that much more needs to be done. A number of surveys of farmers in Canada and the United States have identified inadequate institutional responses as primary obstacles to more widespread adoption of sustainable practices (Wernick and Lockeretz, 1977; Blobaum, 1983; Hill, 1984; Kramer, 1984; Robinson, 1985, 1986; Baker and Smith, 1987; Henning et al., 1990). Recognizing this, Agriculture Canada has been reviewing how its programs, policies, and regulations affect the development of sustainable agriculture (Agriculture Canada, 1989).

Although many proposals for policy change exist, a framework is lacking to assess which ones offer the greatest potential to assist the transition, what time frame is feasible, and which institutional players need to be involved in implementation. Such a framework is proposed here and used to identify key short, medium, and long-term governmental policy, program, and regulatory initiatives to assist the transition.

Sustainable agriculture defined

Sustainable agriculture is both a philosophy and a system of farming. It is rooted in a set of values that reflects an awareness of both ecological and social realities and a commitment to respond appropriately to that awareness. It emphasizes design and management procedures that work with natural processes to conserve all resources and minimize waste and environmental damage, while maintaining or improving farm profitability. This is accomplished by taking into account nutrient and water cycles, energy flows, beneficial soil organisms, natural pest controls, and the humane treatment of animals. Such systems also aim to ensure the well-being of rural communities, and to produce food that is nutritious and uncontaminated with products that might harm human and livestock health. We have elaborated on this definition elsewhere (MacRae et al., 1990).

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Analytical framework

Efficiency - substitution - redesign (ESR)

In previous analyses, we have shown how the evolutionary process of farm-scale transition to sustainable practices involves three overlapping stages: efficiency, substitution and redesign. Of the three, redesign is the most important but has received the least attention (Hill, 1985; MacRae et al., 1990). In the efficiency stage, conventional systems are altered to reduce both consumption of resources and environmental impact, for example, by banding fertilizers, monitoring pests, optimal siting of crops and fields, and optimal timing of operations. In the substitution phase, finite resources and environmentally disruptive products are replaced by those that are more environmentally benign, for example, synthetic nitrogen fertilizers by organic sources, non-specific pesticides by biological controls, herbicides by appropriate systems of cultivation. Because neither of these strategies confronts the causes of problems, they condemn producers to repeated reliance on externally derived curative solutions and inputs.

In contrast, the redesign stage avoids problems by site and time-specific design and management approaches. The farm is made more ecologically and economically diverse, self-reliant in resources, and self-regulating. The various approaches to sustainable agriculture can be arranged using the ESR framework (Figure 1). True sustainability will be achieved by adopting an evolutionary approach that builds on the positive elements of each school of thought listed.

The ESR framework can also be used to suggest and evaluate opportunities for governments to provide supports for the transition in both the content and process of decision making. Efficiency strategies involve minor changes in existing programs and regulations to help create a more positive environment and remove barriers to participation by producers adopting sustainable practices. Such changes can be developed and implemented by working level staff and middle management within bureaucracies because they generally fit currently acceptable methods of policy and program implementation. Of the three approaches, efficiency strategies provide the least threat to decision makers because they are usually least expensive and do not require new legislation, complicated technical analyses, or greater interdepartmental cooperation.

Substitution strategies focus on the replacement of one product or technique by another, or on the addition of a parallel measure with a similar structure but different intent. More levels of govern-

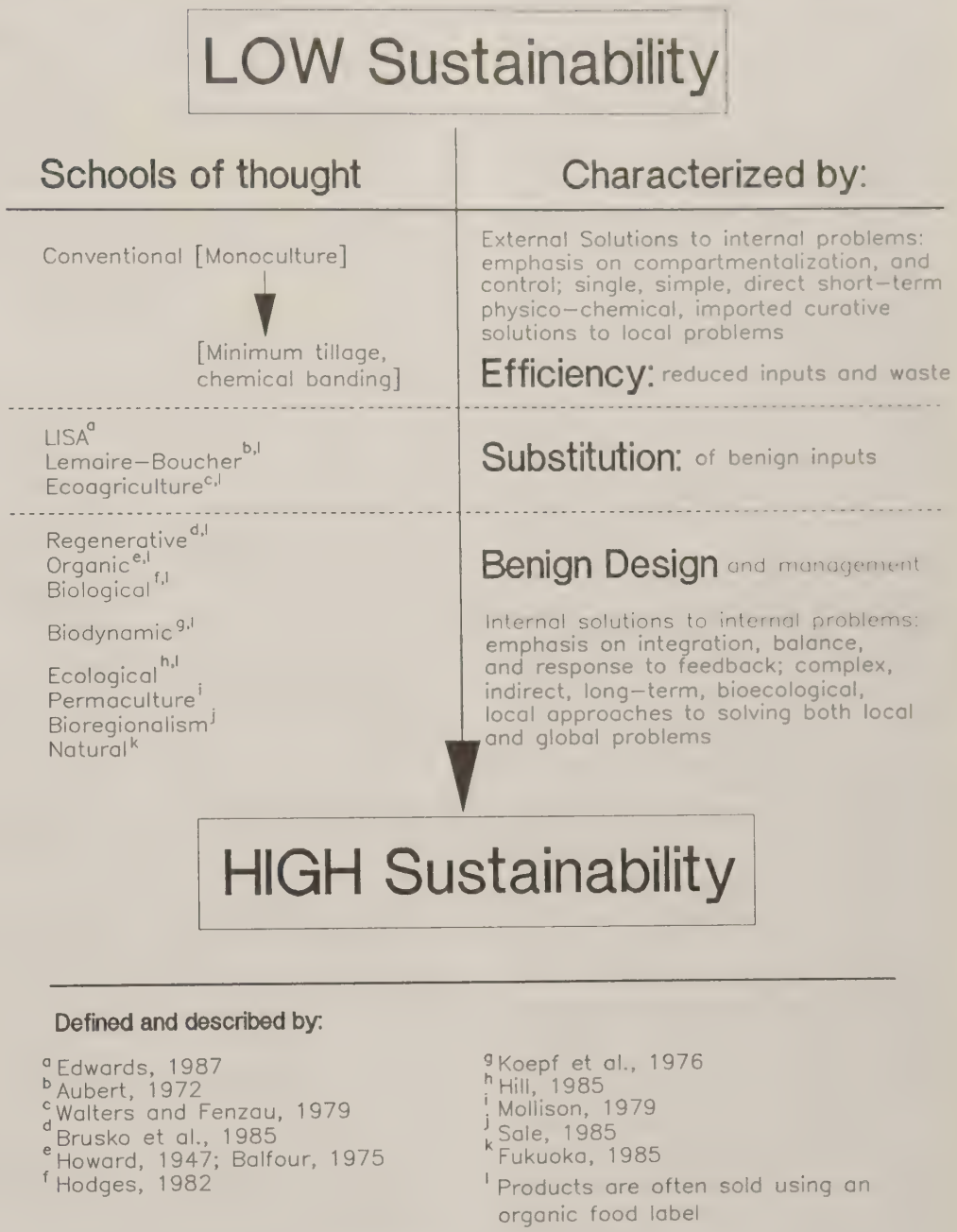

Figure 1. Schools of thought in sustainable agriculture arranged according to an efficiency-substitution-redesign framework.

ment are usually involved, program design and implementation are likely to take longer, and explicit approval by senior managers will usually be required.

Efficiency and substitution strategies may also be used to modify or introduce new public administration procedures to enhance the decision-making process. The deficiencies of Canadian political and public administrative process, and potential efficiency and substitution solutions, have been extensively reviewed by Jackson and Atkinson (1980), Forbes (1985), Beaubien (1986), Pross (1986), Skogstad (1987), Jabes and Zussman (1988), Jackson (1988), Osbaldeston (1988), and Plumptre (1988). Redesign strategies, however, have received little attention; some thoughts on this topic are discussed below.

The redesign approach recognizes the existence of ecological "laws" or principles (Commoner, 1970) and takes these into account in the effort to mimic ecological processes. Many agricultural activities and institutional processes contravene or fail to support these principles (Table 1). The redesign approach takes longer to implement and demands greater changes in the use of human and physical resources, but it is worthwhile in that redesign strategies can generate permanent solutions. Institutional redesign is unlikely to be achieved, however, until government policies and processes have attempted efficiency and substitution strategies and found them wanting. Ideally, efficiency and substitution strategies should be selected for their ability to contribute towards a smooth evolution to the redesign stage. For example, IPM programs designed to eliminate synthetic pesticide use over time are more suitable than those perpetuating inappropriate field and farm designs by basing a control program on pesticides and thereby continuing to provide favorable environments for pests.

Our previous reviews of the literature on the process of transition to sustainable systems (MacRae et al., 1988, 1990) have identified nine key factors to take into account when modifying or designing policies, programs, and regulations.

1. Because transition is an evolutionary process, government initiatives must provide a long-term supportive environment that facilitates passage from one stage to the next.

2. Much of the literature on diffusion of information incorrectly assumes that economic factors are the primary motivation of farmers interested in transition (Heffernan, 1984; Duff et al., 1990). The selection and provision of supports must

Table 1. Principles ("laws") of nature in relation to food production and institutional response*

"Law" of Nature	Some Contraventions	
1. Survival is based on:	Our Food System	Institutional Process
Needs (food, space, shelter, clothing, education and other quality of life factors).	Much of our system is geared to supplying not real, but manipulated needs (e.g., no real need in Canada for refined sugar, coffee, Florida citrus)	Value systems that are rooted in wants vs. ecological realities (e.g., high salary, powerful equipment fueled with non-renewable resources).
Availability of the resources on which these needs depend.	Every stage of food production and subsequent handling is dependent on non-renewable resource inputs (particularly fossil fuels).	Use of analytical tools that employ a short time frame and discount issues of non-renewability.
The incidence of mortality factors	Additional health hazards have been created with the industrialization of agriculture, e.g., machines and toxic chemicals.	"Rewards" for finding solutions to problems by using products implicated as mortality factors.
2. Some key relationships in the environment are cyclical.	The system is characterized by linear nutrient flows with their associated dependence on non-renewable resources and resultant pollution.	Linear, hierarchical decision-making systems without adequate evaluative feedback loops. Organizational paralysis due to "infoglut".
3. Limits exist within the environment which, if not respected, result in its degradation.	Inability of environment to degrade novel chemicals rapidly without poisoning many organisms. Harvesting beyond replacement.	Use of high-powered technologies that transcend limits. Focus on marketable products that can be used irrespective of time and space.
4. Over time, ecosystems tend to increase in complexity, resiliance, and in the functional diversity of their species. Although competition, strife, conflict and parasitism exist in nature, evolution usually depends more on cooperation and sybiotic relationships.	An increasingly complex technology is used to manage more simplified ecosystems, e.g., – reduced gene pool – monocultures – removal of competitors – creation of uniform soil conditions – removal of "non-productive" areas such as hedgerows, wetlands, woodlots. Solutions to problems deal primarily with symptoms.	Designing away variability by simplifying data collection and analysis (e.g., a commodity based development strategy). Single disciplinary teams working in isolation. Centralized control of decision making.
5. Most processes are non-linear and exhibit threshold responses, often with rapid transformation to a complex form with new linkages.	Failing to act on early signs of nitrate accummulation in aquifers. Skyrocketing unpaid costs of environmental clean-up.	Incremental steps toward change. Failure to recognize early warning indicators and causes of problems. Crisis management.
6. Natural ecosystems exhibit numerous benign self-maintaining and self-regulating processes that if interfered with result in degeneration and dramatic population fluctuations.	Application of highly soluble N inhibits symbiotic N-fixers. Pesticides kill natural controls. Boom and bust cycles in certain commodities.	Operating procedures that demotivate employees resulting in high turnover and lack of commitment. Overspending the capital base of the organization.

* (adapted from Hill, 1982, 1988; Walters and Holling, 1984; Dryzek, 1987; Wrabley, 1989)

take into account other motivational factors, such as environmental protection, health, and social justice.

3. Up to now, farmers in transition have obtained most of their information from both popular literature and other farmers. Consequently, the diffusion process should emphasize activities that bring farmers together, for example, short courses, field days, the creation of on-farm research associations, and the establishment of networking newsletters.

4. Farmers in transition tend to be more interested in systems of farming than in specific crops. Thus commodity-based programs can be barriers to transition.

5. Changing the rotation often means that crops are added for which the producer has no marketing experience and for which extra supports are required.

6. Careful planning of the transition is critical, and provision of technical assistance at an early stage can help to avoid many difficulties.

7. Much of the success of the transition depends on access to locale-specific rather than universally applicable information and solutions. Recommendations for research programs and for the training of farmers and extension agents should reflect this reality.

8. Because the transition period involves financial risks, lenders may deny credit to farmers in transition. Farmers with no financial flexibility cannot realistically attempt to convert without financial safety nets.

9. The transition process must be supported by interdisciplinary on-farm participatory research. This is partly because experienced farmers are the main sources of much of the present wisdom.

Other conceptual tools

We have found three other conceptual tools to be useful for developing and refining strategies to support the transition process.

1. Lewin's (1947) Force Field Analysis is a conceptual model that identifies both driving and restraining forces and ways to strengthen and introduce the former and weaken and eliminate the latter. Because of their sensitivity to criticism, public policymakers are more likely to favor new initiatives (driving forces) over those that eliminate restraining forces (Hammond et al., 1983; Lok, 1984).

2. To facilitate the transition process, policymakers need to identify specific supports (education, extension, research), rewards (tax incentives, subsidies, low interest loans), and penalties (regulations, fines, taxes). Penalties are often avoided because of the cost of enforcement and their inability to remove the motivation for acting in an unacceptable manner (Costanza, 1987). Penalties, however, are often more easy to target than are other strategies (OECD, 1988). Although incentive programs (rewards) are often hard to administer (Veeman, 1987), they often cost less than regulatory programs (OECD, 1988). The utility of environmental regulations to control agricultural activities may be limited, however, by insufficient scientific data (Benbrook, 1989). Provision of appropriate supports is generally the most popular strategy unless they are very expensive.

3. It is always important to identify the level at which change is being sought. In sustainable agriculture, the most important operational units are the field, farm, watershed, bioregion, and nation. Action is often required at municipal, provincial, national, and international levels; and cooperation among these levels is essential because ecological operational units transcend political boundaries (Lok, 1984; Lowrance et al., 1986).

Strategies to support the transition

Our focus is on strategies that promote the development of sustainable *systems* of agriculture to address environmental,

Table 2. Canadian policies and programs implicated as impediments to diversification of farming systems

Program, policy, or act	Cited in
Canadian Wheat Board quotas	Senate of Canada (1984); Nowland (1987); Veeman (1987)
Feed Freight Assistance	Same as above
Ontario Drainage Act and municipal taxation	Conservation Council of Ont. (CCO) (1986); Gilson (1987)
Western Grain Transportation Act	Gilson (1987); Veeman (1987); Carmichael and Macmillan (1988); Economic Council of Canada (1988)
Western Grain Stabilization Act	Pidgeon (1984); Gilson (1987); Economic Council of Canada (1988)
Agricultural Stabilization Board	Bond et al. (1986)
Deficiency payment programs based on acres seeded	Carmichael and Macmillan (1988)
Special Canadian Grains Program	Economic Council of Canada (1988)
Federal Fertilizer Act	Greenprint for Canada (1989)
Pesticide registration process	Greenprint for Canada (1989)
Crop insurance programs	Pidgeon (1984); CCO (1986) Gilson (1987); Veeman (1987)
Ontario sales tax exemption for synthetically compounded fertilizers and pesticides	—
Major crops and livestock production subsidies	Bond et al. (1986); Fleming (1987); MacRae (1987); Postel (1987)

economic, and health issues. Several jurisdictions have introduced targeted strategies to reduce agricultural pollution, protect sensitive natural areas, sustain landscape amenities, and keep marginal lands out of production (Duesenberg and Girling, 1984; OECD, 1988). Many of these can be valuable complements to the initiatives presented here. On their own, however, they are unlikely to achieve significant advances toward sustainability.

Efficiency strategies: Removing primary restraining forces

Given the importance of diversity in the efficient functioning of sustainable agroecosystems (Altieri, 1987), it is troubling that many federal and provincial government agronomic and marketing programs and policies have been implicated as impediments to agroecological diversification on the farm (Table 2).

Some of these barriers may be easy to weaken or remove. For example, crop insurance programs could encourage diversification by broadening the concept of good management to include environmentally sound practices and increasing benefits for specialty crops that conserve soil (Pidgeon, 1984; Conservation Council of Ontario, 1986). In the past, farmers who did not use pesticides and fertilizers were regarded as poor managers and were denied coverage. The Canada-Saskatchewan Crop Insurance Program now offers a higher range of coverage for organic grains in recognition of the premiums received (Braidek, 1990).

Other barriers may persist because decision makers have tended to postpone action, especially when no politically viable direction is apparent, until technical analyses generate conclusive data or until the effects of inaction make procrastination unacceptable (Pidgeon, 1984; Manning, 1988). The federal government's Western Grain Transportation Act (WGTA) and the Feed Freight Assistance Program exemplify this phenomenon (Pidgeon, 1984; Senate of Canada, 1984; Gilson, 1987). In both cases, the economic evidence that these programs limit diversification is not entirely conclusive; and the political options regarding changes are controversial.

Specific program and regulatory barriers facing entering or practicing organic farming are listed in Table 3. These either encourage incompatible production practices or limit the marketing of organically labeled produce. Many such barriers could be overcome by hiring professionals familiar with organic farming practices or by retraining current staff. In some instances, marketing boards might also have to invest in capital equipment to store organic products separately from conventional ones.

Substitution strategies

Research, diffusion, and training

Changing the scientific reward and peer review process. The prevailing systems of evaluating scientists restrain the development of sustainable agriculture (MacRae et al., 1989a). To support sustainable agriculture research, reward systems should generally favor: long- over short-term projects; multi-authored over single-authored papers; farmer/extension agent/scientist/social scientist teams over just scientists; projects with on-farm research components over just laboratory and plot studies; projects that comply with departmental vs. disciplinary missions; and popular publications valued at least at par with professional papers.

Exceptions to such reward system criteria include research on basic biological and ecological processes that will help identify appropriate agroecosystem design and management. Our understanding of most pest interactions, many basic soil processes, and symbiotic plant-plant and plant-microbe interactions is still rudimentary (Lowrance et al., 1984; Altieri, 1987). Although some scientists working on these issues may be adequately covered under existing reward systems, most granting agencies have not placed priority on these areas of research.

Training. Also needed are agroecology training programs for scientists,

Table 3. Some specific Canadian governmental and para-governmental regulations and operating practices that restrain the development of organic farming

Agency/system	Problem
Marketing Boards/Agencies	
Wheat Board (Ontario) Potato (Manitoba) Dairy (federal) Soybean (Ontario)	No organic food channels; limited number of wholesalers licensed by board who also buy organic; organic growers not represented on standards committees; organic growers pay for irrelevant services.
Grading	
Egg (Ontario)	No organic food marketing channels.
Fruit (federal)	Encourages use of pesticides to achieve cosmetic perfection, which receives top grade
Health	
Some livestock health regulations, such as those applying to black leg, and warbles (Alberta), and Marek's disease treatments (Ontario)	May contravene certification standards for organic food
Dairy sanitation regulations, specifying use of chlorine/iodine	May contravene certification standards for organic food
Labelling	
Regulations re: labels on packaged imported goods at the retail level	Small volume relative to conventional channels, for which regulations were developed, creates relatively higher costs and labor needs
Credit	
Office du Credit Agricole loan approval systems (Québec)	Often requires evidence of chemical use to approve loan. Often does not recognize existence of premium prices for organic food, so disputes accounts

economists, and other professionals who work in all branches of the department of agriculture. The mechanisms to deliver these training programs already exist. Many farmers are demanding such training, but there are three main barriers to meeting this demand: a) lack of qualified trainers (some private associations have proposed that standards for training trainers be developed, with government assistance for running the programs); b) insufficient technical and financial assistance for developing transition training materials, such as manuals and videos; c) lack of subsidies to cover tuition, travel, and time to permit farmer participation in ongoing courses. Several jurisdictions in Europe offer such subsidies (Peter and Ghesquière, 1988); and the Ontario and Quebec governments have general training programs to which organic farming organizations are gaining access.

Changes to research funding programs. Three main barriers exist for the funding of sustainable agriculture research. First, the recent shift in Canadian federal funding policy means that industrial partners must be found for many programs, an impossible task for most research in sustainable agriculture that focuses on ecosystem design and management. Second, the funding time frame (often limited to a maximum of three years) is insufficient to permit the necessary long-term research. Finally, the peer review process (by specialists within disciplines) discourages acceptance of transdisciplinary sustainable agriculture projects (MacRae et al., 1989a).

In the United States, the Low-Input Sustainable Agriculture (LISA) program has been partly successful in reducing some of these barriers because selections were made by regional committees that understood regional needs. These committees included knowledgeable farmers and extension personnel in addition to scientists, and farmers were involved in the design and implementation of the research program. Also, Congress specifically acknowledged that this kind of research is important, which made scientists feel more secure about participating (Patrick Madden, Manager, LISA program, pers. comm., 1989; Morgan, 1989b; Musser, 1990).

In Canada, more farmer involvement and legislative supports are especially required. The quality of research programs in sustainable agriculture would also be raised by introducing a two-stage funding mechanism whereby the first 6 to 12 months would be used for program development, including an extensive review of the relevant literature and the establishment of a working relationship with involved farmers and extension agents.

Programs in on-farm research. Some of the most successful research in sustainable agriculture is being carried out by farmers working closely with scientists and technical specialists (Thompson and Thompson, 1985; Patriquin et al., 1986; Samson et al., 1989). In the past, however, insufficient technical and financial supports have been given to scientists within Agriculture Canada wishing to do on-farm research (Wanczycki, 1984). However, the on-farm research model is not unknown in Agriculture Canada or provincial departments of agriculture. For example, Agriculture Canada's Prairie Farm Rehabilitation Administration (PFRA) has operated Salinity Cooperatives for several years. A recognized cooperative of farmers arranges with PFRA to hire a technician to assist in resolving salinity problems. In Quebec, extension agents and technicians work with producers in Production Clubs, funded in part by the Department of Agriculture. At present, several Clubs are developing simple on-farm research experiments to solve problems facing producers interested in the transition to sustainable farming practices.

Marketing and quality control. The market for organic foods is dynamic, with emerging opportunities and challenges. However, it is also immature and inefficient (Hall et al., 1989), a problem that can be reduced by policy interventions.

Support for certification. Private certification organizations have been largely successful in ensuring participant compliance with their standards. Verification procedures include on-site inspections, paper audit trails, and independent third party review of applications. These organizations have not had the resources to monitor non-participants, however.

Many states in the U.S. have responded to this concern either by taking on the certification themselves (Texas, Washington, New Hampshire, Colorado, Oklahoma) or by providing regulatory and financial support to non-governmental groups (12 other states including Minnesota, Ohio, California) (CSPI, 1989; MacRae et al., 1989b; Poncavage, 1989). Typically, this support has involved legislating a definition and minimum production and processing standards. In Canada, three provinces (British Columbia, Quebec, Manitoba) have been discussing with private certification organizations a framework for regulatory support. At the federal level, Consumer and Corporate Affairs has published a definition of organic food that is presently enforceable only under the general provisions of existing legislation concerning misleading and deceptive representation of food (Consumer and Corporate Affairs, 1988). Until consumer perception of organic food becomes clearer, the department is unlikely to enforce the definition, even under these provisions (Charles Sheppard, Consumer and Corporate Affairs, pers. comm., April, 1989). In order to reassure consumers, coordinate provincial activities, and ensure access to international markets, the federal government is being advised to provide legislative support for the certification of organic foods (Canadian Agricultural Research Council ad hoc Committee on Natural and Organic Foods, 1990). The form of this support must be determined after full review of the developments in other jurisdictions and with full participation by the organic foods industry.

Market research. There is a significant demand for certain products of sustainable food systems in some regions of the country. A recent study funded by Agriculture Canada identified a strong demand for organic fruits and vegetables in urban centers across Canada (Baseline Market Research, 1988). Demand for other organic products has not been as strong, and producers have not had the resources to identify where it is or how it could be strengthened, such as by greater consumer awareness or clearly identified products (Henning et al., 1990). The fed-

eral government should use some of its resources and expertise in market research in this area. A comprehensive market research program should focus on priority products (livestock and transitional products), pricing, promotion, and distribution.

Improving consumer information. Market inefficiencies are partly caused by insufficient consumer information (Hall et al., 1989). Public demand for information on food production and handling practices is increasing. A vocal segment of the public has been frustrated by a food industry that has for too long unduly influenced decision makers' perceptions of this issue (Hall, 1974; Warnock, 1978; Pim, 1986). The certification of organic food is one way of providing consumers with more information on the practices involved in producing, processing, and distributing food, particularly because it discloses more about the practices involved than government regulations require (Thériault, 1988).

Some progress on increasing consumer access to information, using penalties, is being made in the U.S., particularly in California as a result of the controversial Proposition 65, the "Safe Drinking Water and Toxic Enforcement Act." Similar proposals are being considered in other states (Kramer and van Ravenswaay, 1989; Phipps et al., 1989). In Canada, such a process would have to be initiated either by a provincial or the federal government because the proposition system is weaker, existing only in some municipalities.

Safety net and production incentive programs

Sustainable agriculture crop insurance program. Whereas the efficiency approach involves modifying the definition of good management and the benefits structure for those who are selling their products at higher prices, the substitution strategy involves the introduction of a distinct crop insurance program to support farmers through the transition. The pilot program developed by the Prince Edward Island Department of Agriculture underwrites 50 percent of any yield reduction associated with the transition, up to a maximum of $4200/cooperator/year. During the trial period, this assistance is restricted to coverage on 20 acres or 10 percent of the total farm acreage, whichever is less (Prince Edward Island Department of Agriculture, 1988). The state of Saarland, West Germany offers up to $2500 compensation for any lost income during the transition, the amount depending on family status and year of transition (Peter and Ghesquière, 1988).

Credit assistance. Governments in Canada have traditionally supplied credit assistance to farmers and used credit policy to shape agricultural structure and practice. This approach could be used to promote sustainable agriculture. For example, the province of Quebec's "An Act Respecting Farm Finance" contains a section (Section 3--Special Loans) that might be an appropriate vehicle to provide this kind of credit assistance. It provides for credit and a subsidy to producers who need to change their production system because of severe economic dislocations. Of particular relevance is the provision to lend sufficient funds for conversion and living expenses (subject to a maximum) until alternative production practices are suitably established. Modifications to this act could easily be made to include farmers converting to sustainable practices.

Production subsidies. Combined with credit policy, subsidies have been used to encourage production of particular commodities. Some analysts propose that they be used to encourage sustainable agriculture, with one major conceptual difference. Subsidies should be designed to support production systems rather than specific commodities and to incorporate externalities.

In Europe, the Danish government provides development grants and transition subsidies of about $350/ha (for a three-year period) to converting farmers as part of their 10-year program to convert 10 percent of the country's agricultural land to oganic farming. This strategy is controversial. Some believe the encouragement to be insufficient (Stopes and Woodward, 1988). Others see the subsidies as penalizing those who have already converted or fear that the marketplace will be flooded with organic food, thereby eliminating the organic premium (British Organic Farmers and Organic Growers Association, 1988). Because of the equity question, Sweden's organic farmers receive the same level of support as those in transition (Rundgren, 1989).

Subsidies often present problems. Past subsidy programs have favored larger-scale operations, often to the detriment of the smaller ones (Rodefield et al., 1978; Troughton, 1985; Heffernan, 1986; Strange, 1988). Furthermore, the practices that the subsidies have been designed to encourage may be abandoned when the subsidy ends (Swanson et al., 1986). Some European policy analysts have hoped to avoid this problem by requiring that eligible farmers belong to an organic certification agency. Then, abandonment of organic practices results in withdrawal of the certification label and associated financial penalties. Limiting the duration of the subsidy would also be important to avoid capitalizing it into agricultural assets.

Tax provisions. Taxation policy has long been recognized as one cause of our present agriculture problems. As a first step toward change, we need a comprehensive review, similar to that recently undertaken by the Natural Resources Defense Council (NRDC) in the United States (Ward et al., 1989), of how the Canadian tax code specifically discourages sustainable practices. The NRDC report identified the environmental importance of removing agricultural tax shelters, the bias to overproduction from cash accounting and the treatment of capital gains and expenses for fertilizer and lime, and incentives for bringing marginal land into production. The NRDC proposed ways to avoid both undue penalties on farmers and unnecessarily large administrative burdens.

Tax policy can be changed to create different kinds of rewards and penalties. For example, the Rhode Island Division of Agriculture and Marketing is considering a proposal to reward farmers who follow recognized sustainable practices by eliminating their property taxes (Frisch, 1989). Many Canadian provinces already have property tax rebate programs that could be altered to encourage sustainable production practices (Conservation Council of Ontario,

1986). On the penalty side, a pollution tax could be applied to synthetic fertilizers and pesticides to better reflect their social and environmental costs (Costanza, 1987; Fleming, 1987; Postel, 1987). Some have proposed low tax levels (around 1 percent) to generate funds for monitoring pollution and for conducting research on alternatives (Fleming, 1987; Postel, 1987; Ward et al., 1989). This approach may appeal to policymakers because costs are low, money is raised for other budget areas, and consumption is not restricted so much that the chemical lobby would be very actively opposed. It does not, however, fully reflect the polluter pays principle to which some jurisdictions are committed. Also, this level of tax is not likely to reduce pollution in the short term (Daberkow and Reichelderfer, 1988; OECD, 1988). A higher tax level would have greater allocative effects (Koopmans, 1987; Weinschenck, 1987; Maass, 1989).

A general problem with input taxes is that efficient, responsible, nonpolluting users of synthetic chemicals are also penalized (OECD, 1988). Furthermore, such a tax would require an administrative effort and could raise consumer prices.

Pollution taxes on agricultural chemicals have been imposed in several jurisdictions in the United States and Europe and are under consideration elsewhere (Postel, 1987; OECD, 1988; Benbrook, 1989). However, in Canada, decision makers' interest in such penalties may only be triggered by high levels of contamination and a massive lobbying effort by environmental groups.

Goldsmith (1988) proposed two other tax strategies: an amortization tax inversely related to the estimated life of the product, for example, 100 percent for a product designed to last less than a year and no tax for something designed to last 100 years (exempt goods would include food and some hygiene products); and a transport tax to encourage use of local products.

Clearly, penalties of this nature are controversial, with both winners and losers; but these taxes could complement other transition initiatives.

Redesign strategies

The above strategies support incremental change towards sustainable agriculture. They only partly address the sources of our agricultural problems and the institutional structures and processes required to support a comprehensive transition. What is required is an extensive redesign of institutional form, processes, and interventions to reflect ecological laws and food system goals, and to implement strategies to create a truly sustainable agricultural system. The intent in discussing redesign strategies here is not to be conclusive, but to identify key issues and propose potential solutions that must be considered. Many important conceptual questions are not being asked by agricultural professionals (Lockeretz, 1988). Present deficiencies in our political process have meant that no mechanism exists for a far-ranging and participatory discussion of appropriate goals for a sustainable system. A preliminary list of such goals and their relationship to ecological principles is provided in Table 4. The critical challenge is to refine them, reconcile their contradictions, evaluate their implications, and develop appropriate action plans. Some of their implications are examined below.

Changing the role of the state in agricultural development

The Canadian government has used agriculture primarily as a tool to achieve other objectives, particularly to meet national economic objectives (Veeman and Veeman, 1976; Warnock, 1984; Forbes, 1985; Skogstad, 1987). This is consistent with the historic role of the state in Western democracies (Bookchin, 1989). This limited economic role for the state is now widely perceived to be deficient because it relies excessively on the market as a vehicle for satisfying human needs (Henderson, 1981; Robertson, 1983; Ekins,

Table 4. Goals for a sustainable food system and their relationship to ecological principles ("laws") (Adapted from Cornucopia Project, 1981; Hill, 1982; Dahlberg, 1985)

PARAMOUNT GOALS OF THE FOOD SYSTEM	Nourishment Human development and fulfillment Environmental sustainability
SUB-GOALS	
Consumption	
A. **Adequacy:** should give every person access to sufficient food in quantity, quality and degree of choice, to achieve optimal physical and mental health. (1,3)*	
B. **Appropriateness:** should be matched in production, consumption, recycling, thermodynamics, and technology to both the limits and needs of its region and locality. (2,3,6)	
Security	
C. **Dependability:** should provide every person with a reliable food supply—free from social, political, economic and environmental disruption. (4,6)	
D. **Sustainability:** should be culturally, environmentally, economically, and technologically sustainable with respect to production and all other aspects of the food system, including resource inputs, cultivation techniques, processing and distribution. (all)	
E. **Safety:** should minimize danger to workers, consumers, and the environment. (1,3)	
F. **Efficiency:** should practice resource efficiency by incurring minimal resource costs (energy, water, soil resources, genetic resources, forests, fisheries and other wildlife). (1,6)	
Equity	
G. **Wealth:** should generate sufficient income to food producers to provide a quality of life (measured by a variety of indicators) equivalent to that of other sectors of the economy, to maintain vigorous rural communities and enable farmers to fulfill their land stewardship responsibilities. (4,6)	
H. **Flexibility:** should be open to growth, evolution, creativity, and experimentation to deal with climatic, economic and political stresses and variability. (4,5,6)	
I. **Participation:** has its organization, decision-making process and course towards the future determined by all sectors of the population that wish to be involved. (4,6)	
J. **Human development and fulfillment:** must provide opportunities for creative and fulfilling paid and unpaid work, social interaction, psychosocial evolution and social justice. (4)	
K. **Support:** should interact with the food systems of other nations in such a way that they are able to achieve similar goals, including a sustainable food system. (1,6)	

* Numbers in brackets refer to the principal ecological "laws" (Table 1) on which these goals are based.

1986), and it tends to transfer resources and power to a ruling elite (Mitchell, 1975; Newman, 1979; Buttel and Newby, 1980; Francis, 1986; Bonanno, 1987). Few countries have made significant progress toward addressing these deficiencies.

Designing the food system around the optimal diet

If the central goal of the food system is to achieve optimal nourishment of the population, then the methods employed should minimize compromise. Although most of Canada's population does not go hungry, malnourishment is widespread and is reflected in the high incidence of food-related degenerative diseases. A growing body of research on the effects of production systems on food quality suggests that the optimal diet should include foods without pesticide residues (Pim, 1981; Clancy, 1986; National Research Council, 1987; Robbins, 1987), antibiotic residues (Holmberg et al., 1984, 1987; Spika et al., 1987), and food additives (Lawrence, 1986; Pim, 1986). They should be produced with a complete, balanced fertilization program, not just nitrogen, phosphorus and potassium, which may suppress the uptake of certain other essential elements (Voisin, 1959; Albrecht, 1975; Petterssen, 1978; Knorr and Vogtmann, 1983; Linder, 1985). In animal production systems, confinement and dietary stresses should be minimized (Boehncke, 1986, 1988). Ten years ago, the Science Council of Canada (1979) proposed that Canada move towards an optimal diet scenario, but little progress has been made.

Other governments have followed the optimal diet approach. In the 1970s, Norway set out to design its food and agriculture production and distribution system around an optimal diet and adjusted its policies accordingly (Norwegian Ministry of Agriculture, 1975). By setting goals and establishing appropriate institutional supports, they have been able to change the way the food is produced and distributed. They had four main goals: to stimulate the consumption of healthy foodstuffs (for example, grains, potatoes, and polyunsaturated fats) and decrease consumption of unhealthy ones (for example, saturated fats, refined sugars) in order to reduce the incidence of some chronic diseases; to develop guidelines for food production as recommended by the World Food Council; to increase domestic food self-reliance from 39 percent of total calories to 52 percent by 1990; and to promote regional development. Various tools have been used to achieve these goals: production and consumer subsidies, marketing promotion based on nutritional quality, consumer education programs, improved labeling systems, and legislation to penalize the production of food and drink detrimental to health (Ringen, 1977). However, the government recognized that taste cannot be legislated, and that the marketplace will still play a central role in food purchasing patterns (Winikoff, 1977).

The Norwegian strategy has produced some positive results. Self-sufficiency reached 50 percent by 1988, and fat as a proportion of energy in the diet dropped from 40 percent (1975) to 37 percent (1987), although some undesirable fats have been inadvertently subsidized. Consumption of whole grains, fruit, and low-fat milk is up; and potato and grain quality has improved. A decline in cardiovascular deaths has been partly attributed to the Nutrition Policy. Farmers have achieved income parity with industrial workers (Milio, 1988). Similar kinds of initiatives, mostly at the municipal level, are under way around the world (Haughton, 1987; Toronto Board of Health, 1988), some associated with the World Health Organization's Healthy Cities Project (Hancock, 1989).

Implications of dietary needs for system design

The main implications for redesigning the Canadian food and agriculture system to achieve an optimal diet are profound. They include:

1. Major redesign of the farm ecosystem to eliminate most synthetic agrichemicals from the production process (MacRae et al., 1990).

2. A shift in emphasis toward animal production systems that reduce carcass fat. This could involve some combination of reducing concentrates in livestock diets (Norway proposed this), lengthening the growing period, and increasing forage intake (National Research Council, 1988; Solomon and Lynch, 1989). Changes of this nature would have substantial implications for management and design of farms, and for land use since many livestock enterprises in Canada are structured around a high concentrate diet and rapid fattening. Many farms rely on purchased feed and have insufficient land to grow their own grains and forages. Manure disposal is an associated problem.

3. Focus on fresh food production and minimal processing. Canadians have been consuming more fresh food for some time (Kramer, 1989); this trend could be supported, at least during the growing season, under an optimal diet scenario (Grimme et al., 1986). This will require more highly developed regional distribution systems. There are also significant implications for the food import and export economy (see below).

The processing industry would become more seasonal. Demand for many processed products would slump dramatically during the Canadian growing season, but rise substantially during the off-season, particularly if fresh imports were restricted to meet other sustainability goals. This may be desirable from an optimal diet perspective, as there is some evidence that properly frozen or canned local produce is nutritionally as good as, or even superior to, "fresh" produce shipped over long distances (Kramer, 1989). Herrin and Gussow (1989), in a preliminary analysis of a sustainable diet scenario for Montana, suggested that much greater reliance on local produce year round would not create nutritional problems. The difficulties created for the processing industry would have to be addressed, however. Certain forms of processing would be discouraged: removal of fibre from grains; bleaching; addition of salt, refined sugar, and food additives; and boiling in fat, oil, or water (Hall, 1974; Silverstein, 1984; Grimme et al., 1986).

4. A more diverse diet, from a sustainability perspective, requires a more diversified production system. To meet other sustainable agriculture goals, this diversification should be achieved within

farm units rather than by creating specialized production systems to produce new crops. Opportunities for limited diversification in animal feed and industrial crops are being promoted (Campbell, 1987; Joliffe and Snapp, 1988; Joliffe, 1989), but opportunities for imported human foods substitution have not been well explored. Herrin and Gussow (1989), in one of the few studies on the topic, concluded that Montana could meet all its winter vitamin C requirements with local production of potatoes, cabbage, and sprouted seeds. No imported citrus or out-of-season fruits and vegetables would be required.

Addressing consumer choice

Consumer choice is a major concern. In Norway, food production and nutrition information was provided to motivate better dietary habits and to develop skills for making more informed food choices. The government recognized that "present marketing practices are in relatively large disaccord with the nutritional objectives...The factors which today regulate sales are only to a small degree dictated by nutritional considerations" (Norwegian Ministry of Agriculture, 1975). These words also describe Canada's situation. Strategies for addressing this marketing problem have been discussed in previous sections. Ultimately the marketing and advertising of food must have as the central principle that consumers be provided an opportunity for "fully informed" choice. This requires that policymakers believe that people are capable of making informed decisions when provided with full, comprehensible information and that marketers and advertisers be committed to, or forced into, providing more substantial information on their products.

Consequently, changes would be required for grading, labeling, and advertising. Grading systems presently reflect largely cosmetic, rather than nutritional, criteria (Pimentel et al., 1977; McKinney and Gold, 1987; Feenstra, 1988). Instead, grades should reflect the products' compliance with the optimal diet criteria. An example is provided in Table 5. Current labeling regulations are based on a very narrow conception of nutrition. Little information on the food production process is provided, and often incomplete information is included concerning ingredients, nutritional value, and possible contaminants. A recent survey by the Grocery Products Manufacturers of Canada concluded that 80 percent of today's consumers read ingredient labels on packaged foods, up from an estimated 2 percent in 1983 (Bertin, 1989). Unfortunately, only about 20 percent of packaged foods in Canada carry nutrition labels (Grier, 1990). A comprehensive index system could be included on labels to indicate compliance with optimal diet and other sustainability criteria. An example of such a label is provided in Table 6. Although not easy to create, the federal government's "Environmentally Friendly Products" program, operated by Environment Canada, provides a base of experience, in terms of both data and process. Also, several nonprofit organizations promoting ethical investment and purchasing have developed systems for rating products (Will et al., 1988; Pollution Probe, 1989).

In 1986, Canadian grocery retailers spent $2.5 billion on advertising (Matas, 1987). Although advertising can contribute to market efficiency by providing consumers with information, it can also be part of an insidious process of misinforming and partially informing the public (Singer, 1986). The costs of such misinformation are borne by its victims, directly in product prices and indirectly in lost government tax revenues, because advertising expenses receive preferential tax treatment (McQuaig, 1987). Some studies have suggested that advertising is not often cost effective and that it contributes to waste, monopoly, and higher prices (Singer, 1986). Although advertising regulations exist (Consumer and Corporate Affairs, 1988), the focus is on preventing fraud and not on the provision of full product information.

The Science Council of Canada (1979) proposed that advertising of nutritionally questionable products be curtailed by government intervention. This could be one component of an integrated strategy to promote an optimal diet and eliminate or restrict any advertising that constitutes a barrier to achieving this goal. One possible requirement might be that food products that are clearly undesirable or peripheral to an optimal diet be labeled as such.

Weaning Canada from the import-export agricultural economy

Canada enjoyed a balance of agricultural trade surplus of $2.12 billion in 1987 (Aube, 1988). Grain exports have been the major contributor to this positive trade balance, with $5.12 billion in export grain sales in 1987 (Aube, 1988), mostly from prairie production. The other regions of Canada, however, are net importers. Our reliance on the prairie grain economy for a favorable agricultural trade balance has placed undue economic and environmental pressure on a narrow range of production sectors and practices. Dependence on imported food, on the other hand, has resulted in

Table 5. Example of current vs. redesigned grading criteria for melons (Canada #1)

Current[1]	Possible redesign
1. Fairly clean, well formed, mature, well netted for the variety, sound, of one variety and do not, when in a package, vary more than 1.5 in. in diameter 2. Free from insects, insect larva, insect injury, disease, decay, sunscald, moisture injury, cracks or hail marks 3. Free from any injury or defect or combination thereof, other than an injury or defect referred to in paragraph 2, that affects the appearance, edibility or shipping quality of the melons	1. Produced in accordance with standards of a recognized sustainable agriculture production system 2. Harvested within 3 days of optimal harvest date and made available to consumers within 3 days of harvest 3. Free from any injury, defect, insect or disease damage that affects the keeping and nutritional qualities of the melons

[1] Reg. 332, Farm Products, Grades and Sales Act.

Table 6. Hypothetical example of a label for an instant baby food cereal[1]

	Rating
Contents: Whole wheat	
Production: Certified organic (biological method)	8[2]
Processing: Regular milling: excessive heat	5[3]
No supplements	10[3]
Milling by-products recycled	7[4]
Product distribution: Local	8[5]
Food analysis[6]: Medium fibre	6
No sodium	10
No sugar	10
Low fat	8
Medium trace minerals	6
Medium important vitamins	6
Social justice[7]: Safe working conditions	8
Wage rate is below industry average	5
Preferential purchase of raw materials from the region	8
Minimal pollution	8
No donations made to charities	0

[1] This figure is presented for illustrative purposes only. Clearly an enormous amount of work would have to be invested in collecting relevant information, designing appropriate educational materials, indices, labels, administrative procedures and funding strategies. We also recognize the difficulties of developing general numerical scales for such complex subjects.
[2] Using a sustainability scale identified in Figure 1.
[3] Based on Grimme et al. (1986) classification of processing methods and their desirability for the human diet.
[4] Based on a scale—10 No waste products; 8 By-products reused in same process; 6 By-products recycled in another process; 4 By-products partly recycled; 2 By-products incinerated; 0 By-products are an untreated pollutant (cf. Jackson and Weller, 1983).
[5] Based on scale: 10 Direct; 8 Local; 6 Regional; 4 National; 2 International (cf. Cornucopia Project, 1984; Harnapp, 1988 regarding the economic benefits of different distribution systems).
[6] Index of compliance with nutritional content of product from ideal production, processing and distribution conditions. These ideals, at a minimum, could be produced from existing nutrient content data.
[7] Cf. Will et al., 1988. Each social justice element receives a separate rating.

resource inefficiencies (those that are largely considered externalities because they are not measured in the marketplace) and a less nutritious food supply. In this section we examine the argument that designing a truly sustainable food system requires that we become much less dependent on the import-export economy.

Self-reliance

Policies of self-reliance are controversial, especially in our present free trade environment. In the 1989 Throne Speech, the Canadian government expressed its desire to facilitate the development of a more self-reliant agricultural sector, but its interpretation involves a very shallow "commodity" and market oriented understanding of the concept without acknowledgment of the broader ecological viewpoint. The rationale for self-reliance has been detailed elsewhere (for example, Science Council of Canada, 1979; Warnock, 1982; Morris, 1982; Ekins, 1986; Meeker-Lowry, 1988; Kneen, 1989), and the general principle has been outlined by Meeker-Lowry (1988): "Self-reliance in socioeconomic systems has its analogue in natural systems. As a general rule of natural process, energy (and subsequent action) are captured or expended as close to the point of origin as possible."

Harnapp (1988) has listed four problems of import reliance: increased vulnerability to disruption of the food supply (for example, Chilean grape incident of 1989, 1981 California Medfly scare); energy inefficiency and costliness (transportation costs amount to 8 percent of consumer supermarket expenditures, without considering unmeasured externalities); less nutritious food (for example, vine-ripened tomatoes can have 25-30 percent more vitamin C compared to those ripened with ethylene gas); and a local economy potentially weakened by monetary leakages ($4 billion left Ontario in food import expenses in 1985, or 80 percent of the amount spent; that is, only 20 percent of consumer expenditures on imports remained in the province).

Generally, strategies for building self-reliance have three elements: plugging resource and monetary leaks; encouraging new enterprises to build on local strengths; and promoting businesses that can build on underutilized resources (Rocky Mountain Institute, 1986).

Canada could plug several leaks in its food economy. For example, just after World War II, Canada was self-sufficient in plums, peaches, apricots, strawberries, and pears; but by 1980, 28 to 57 percent of these five fruits were imported (Warnock, 1984). In 1987, Canada was 71 percent self-sufficient (production as a percentage of disposition) in fresh vegetables, 90 percent in canned vegetables, almost 100 percent in frozen vegetables, and 45 percent in fruits and berries (Statistics Canada, 1988). However, such national figures hide regional differences. For example, Saskatchewan was estimated to be only 10 percent self-sufficient in vegetables (Canadian Organic Producers' Marketing Cooperative, 1984). Some of this is explained by the seasonality of Canadian production and the limits on storage; but many products, such as cabbages, onions, and carrots, are still imported during both production and ideal storage periods (Warnock, 1984). Over the years, Canada has lost much of its processing capacity in certain sectors, such as tomatoes (OPIRG, 1979). We are now net importers of apple juice concentrate (Aube, 1988) even though we produce large quantities of apples.

Changes to land use patterns

The loss of prime agricultural land is one of the greatest threats to self-reliance and the sustainability of Canadian agriculture (Bentley, 1980). Between 1951 and 1986, over 6.5 million acres of agricultural land, approximately 12 percent of the land base currently capable of

supporting agriculture, was lost to other uses (Burke, 1988). Between 1966 and 1981, 57 percent of all rural land converted to urban uses was prime farmland (Class I-III) (Yeates, 1985). This trend is projected to continue.

Warnock (1982), in his study on self-reliance in British Columbia, expressed concern for the loss of the land base in fruits and vegetables. He concluded that maintaining self-sufficiency at 47 percent would require a 40 to 60 percent increase in production by the year 2000. Even so, this would still leave the province far short of its desired objective of 65 percent self-sufficiency in these products. Harnapp (1988) concluded that Ontario would need over 9 million acres of land in food production to be totally self-sufficient at present consumption patterns (presently just over 8 million acres are in production, but some of that is in non-food crops, such as tobacco). A major decline in red meat consumption would dramatically decrease Ontario's land needs (Harnapp, 1988). Similarly, Eastern Canada (from Ontario to the Maritimes) would likely need to reduce the current levels of dairying if it wished to reallocate land use to achieve greater self-reliance (Warkentin and Gertler, 1977).

A variety of strategies for preserving agricultural land have been used in Canada with varying degrees of success (Science Council of Canada, 1979; Furuseth and Pierce, 1982). The two provinces with the greatest pressures from urbanization, Ontario and British Columbia, despite a variety of planning and legislative approaches, have not succeeded in substantially reducing the rate of loss (Warren et al., 1989). Many legislative strategies have proved successful in other countries (Steiner and Theilacker, 1984) and should be examined for their relevance to Canada. For example, community land trusts (Institute for Community Economics, 1982) and conservation easements (Sand, 1985; Ward et al., 1989) could be effective in Canada with appropriate government supports.

Redesigning the management of government to assist transition

Current government management systems have several shortcomings: a lack of long-term direction; weak control by individual units over their resources; too many different relationships to maintain; a lack of clear indicators of success and failure; a lack of flexibility for providing rewards; stifled creativity, which diminishes the contribution of the individual in favor of the institutional culture; and paralysis associated with "infoglut" (Plumptre, 1988). There has been a tendency to hope that sustainability problems can be solved technologically, and to postpone dealing with the institutional and psychosocial roots of the problems (Hill, 1986). To achieve sustainability, fundamental changes in the design and management of our institutions are required. The redesign of our food system is dependent on the simultaneous redesign of the involved government departments so that both become fully responsive to ecological realities (Wright, 1989). What follows are proposals for the redesign of institutions to enable them to respond to ecological realities, in this case, sustainable agriculture.

Organizations have their own ecology (Plumptre, 1988; Morley and Wright, 1989), which can mimic the ecology of the natural systems with which they are concerned (Walters and Holling, 1984; Solway, 1988; Morgan, 1989a). Some management theories have recognized and applied this concept to business organizations (Peters and Waterman, 1982; Wright and Morley, 1989). Morgan (1989a) has stated that, "the internal diversity of any self-regulating system must match the complexity of its environment if it is to deal with the challenges posed by that environment." To achieve this, an organization must be structured as a miniature ecosystem, containing symbiotic, catalytic, and complex webs of relationships, processes, and systems (Plumptre, 1988; Kolodny, 1989).

In Table 7, some organizational implications of current management practices for agricultural organizations are related to the ecological laws discussed earlier. These ideas are particularly important for government units that deal with intangible outcomes that cannot be controlled or predicted, such as departments of agriculture. They are less important for units whose work is routine and often involves physical goods (Plumptre, 1988). The most critical ecological realities for organizational design relate to law #5 (Table 1), the tendency for ecosystems to transform in radical, unpredictable ways when certain thresholds are crossed (Solway, 1988). Such transformations are often both large and physically or economically irreversible (Walters and Holling, 1984). In agriculture, examples of these transformations include the fairly rapid development of a farm financial crisis in the early eighties and the appearance of high concentrations of agricultural water pollutants. The organic food industry appears to be experiencing a threshold phenomenon at present. After years of being perceived as a marginal agricultural activity, organic food production is suddenly unable to keep up with demand. Agricultural professionals are studying organic farming systems at unprecedented levels, and government departments are scrambling to develop policy initiatives and supports to accommodate this system. In most cases, governments have been slow to recognize the nature of the threshold and have failed to take appropriate action, primarily because the ways in which institutions are organized do not correspond to the realities of the organic "environment."

How should organizations be designed to be able to respond quickly and effectively to such thresholds? First, they must be able to recognize the approach of a threshold by monitoring early indicators. This requires that the organization be close to its "clients" and their environment. It must have well-established intelligence networks that do not collect all the information available, but instead focus on the key indicators that herald changes and trigger institutional responses (Table 8). A continuous feedback process is also required to monitor the outcomes of actions taken and suggest modifications to future actions (Morgan, 1989a). Problem-solving teams staffed by generalists, with broad assignments that allow them to reorganize for each new task, should be formed to be able to respond to emergent problems (Morgan, 1989a). Such teams may "compete" in the development of appro-

Table 7. Some implications of ecological "laws" (Table 1) for organizational design of government departments

Design	Responds to "Law"
1. Organization has clear long-term purpose, well-understood by all employees (Peters and Waterman, 1982; Beaubien, 1986). The evolution of the organization is clear and consciously planned (Plumptre, 1988).	1
2. Shift decision-making power to people closest to the environment (staff level, middle managers) (Peters and Waterman, 1982; Johnson and Frohman, 1989).	2
3. Develop more lateral, as opposed to vertical, lines of communication (Johnson and Frohman, 1989) (meetings across unit lines, outside unit peers involved in staff evaluation).	2
4. Make decisions before all the of information is in, based on both technical and qualitative data (Veeman and Veeman, 1976; Ulrich and Wiersema, 1989), and on identified key variables that indicate the functioning of the whole (Walters and Holling, 1984). Monitoring key variables is the key to management (Peters and Waterman, 1982).	2,5
5. Spread risk by investing in more than one approach to solving a problem (Plumptre, 1988; Ulrich and Wiersema, 1989). Strive for redundancy of function, not redundancy of parts (Peters and Waterman, 1982; Morley, 1989). Disaggregate to create many operating units, each with low cost of failure (Walters and Holling, 1984).	4
6. Introduce evaluation systems in which employees share the risks and benefits of the organization (Ulrich and Wiersema, 1989).	1
7. Design management standards around the needs of each unit (Osbaldeston, 1988). Managers focus on empowering employees to make them more effective contributors to the goals of the unit (Evans and Russell, 1989).	4,6
8. Hire generalists of different backgrounds who can work in different teams. Teams work on different tasks, depending on needs (Morgan, 1989a).	2,4,5
9. Establish minimum organization specifications and control that conserve organizational resources and allow for spontaneous internal reorganization to adapt to changing conditions (Peters and Waterman, 1982; Morgan, 1989a).	5,6
10. Store up outputs (human resources, ideas) in times of surplus for release during periods of deficiency (already done in case of some physical goods) (Walters and Holling, 1984).	3,4,6
11. Establish open-ended networks of interdependent allies, inside and outside the organization, to build collaborative solution finding (Solway, 1988; Morgan, 1989a).	5,6

priate solutions, each approaching the problem from a different angle. This approach, known as "redundancy of function," spreads risk and produces greater diversity of thought and action (Morgan, 1989a; Morley, 1989).

Such changes need not be perceived as radical departures from existing practice. Canada's Auditor General (1988) has identified several governmental units that already operate in accordance with some of these principles. They emphasize people, participatory leadership, innovative work styles, strong client orientations (ear to the ground), and optimum performance. The task is to build on such positive models.

Conclusions

Our intention in this paper has been to identify how Canadian governments might move forward in an incremental, evolutionary way while, at the same time, maintaining a long-term, broad development perspective. Some successes will result with each incremental step, but only when the redesign stage has been achieved will we have crossed the necessary threshold to achieve a truly sustainable agriculture. Success can only be achieved by taking action on all levels and on a wide range of strategies. To focus on only a few of the initiatives outlined above could be self-defeating because it gives the illusion of significant change. Just as sustainability requires diversification on the farm, so is it required in the policy arena.

As governments begin to implement immediately achievable efficiency and substitution strategies, they should commission new studies on long-term design and management of the food system. We recommend, in particular, studies be initiated on the following:

1. End use analysis. Some success has already been achieved using this approach in the energy field (Lovins and Lovins, 1982; Brooks et al., 1983). This is a good example of a design strategy that focuses on future desirable goals and then investigates sustainable ways of achieving them.

2. Initiatives to finance a transition to sustainable agriculture. It appears that a shift to sustainable agriculture could, over the long term, reduce government expenditures in several areas, including subsidies and environmental and health care costs (Ward et al., 1989; MacRae et al., 1990). Priority studies include detailed analyses of potential savings and the manner and schedule by which such savings might be used to finance other initiatives to promote sustainability.

3. The optimal diet scenario and its systemic implications. Some preliminary work has been done on this, but much more detailed analysis is required to identify the least disruptive ways in which it might be achieved.

4. The design of optimal reward systems for agricultural professionals to enhance their competent involvement in sustainability.

5. Study of the implications of widespread adoption of sustainable practices in Canada.

6. The design of a participatory goal articulation process for the Canadian food system.

7. Redefining risk in an ecological context and investigating the associated policy implications. Our current concept of risk is too limited, and the implications of adopting ecological concepts of risk for government and private institutions have yet to be explored.

Finally, we cannot stress enough the dangers of compromising the long-term in the quest of short-term successes. Sus-

Table 8. Some potential threshold indicators in agriculture based on an ecological analysis

Threshold indicator	Phenomenon
1. Development of pest resistance to a pesticide	Aggravated pest problem (Dover, 1985).
2. Pest outbreaks and development of secondary pests	Inappropriate design of agroecosystem (often excess N or excessive use of pesticides) (Chaboussou, 1982; Patriquin et al., 1986).
3. Soil degradation	Inappropriate design of agroecosystem (often inappropriate crop rotation and tillage) (Reganold, 1988)
4. Breakdown of rural families	Financial stress and degradation of rural community (Walker and Walker, 1988; Small et al., 1989)
5. Increasing need for government subsidies to support farm income	Biological capital of system is overdrawn (Henderson, 1981; Cox, 1984).
6. Consumer fear (real or perceived)	Unsuitability of product or process, e.g., Alar, food irradiation, BST, Texas response to EEC beef hormone dispute (Presnal, 1989)

tainability transcends short-time horizons. As the Bruntland Commission report (WCED, 1987) has argued, concern for future generations must become an integral part of our institutional culture.

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Sustainable Resource Development in the Third World. 1987. Edited by Douglas D. Southgate and John F. Disinger. Westview Special Studies in Natural Resources and Energy Management. Westview Press, Boulder, Colorado, and London. 177 pp. $22, paper.

This book is a product of "an international symposium involving both invited and contributed papers addressing the technological and institutional challenges of the sustainable development of natural resources in the Third World." The symposium was staged in September, 1985, in Columbus, Ohio, and sponsored by Argonne National Laboratory, the Tropical Renewable Resources Program and the School of Natural Resources of Ohio State University, and the United States Agency for International Development.

While the title leads a reader to expect a coherent discussion of sustainable resource development in the Third World, the volume actually constitutes merely a partial proceedings of that symposium. As such, it is disappointing. It includes many "nuts and bolts" statements about international development and makes some fine suggestions. But it lacks a broad conceptualization of what "sustainable resource development" is and how it may be different from "unsustainable" resource development.

The book is well organized. It begins with an overview of four different projects, which is followed by a section on social science analysis. The next section presents five case studies. The subjects are quite relevant, including social forestry, soil erosion, renewable energy, and watershed management. However, there is more description of weaknesses in project activity than of strengths or of improved strategies. For example, commenting on the chapter entitled "What are the Soil and Water Benefits of Planting Trees in Developing Country Watersheds?" the editors state that the authors "present an annotated primer of the unwarranted assumptions regarding the benefits of third world afforestation. They caution that raising unrealistic expectations about those benefits either purposefully or by default is ultimately self-defeating for resource planners and managers."

The next chapter on renewable energy projects in developing countries features a long list of "barriers" to the development of renewable energies but does not offer much help on how to overcome them. Chapter 8, by Richard B. Norgaard, does offer a "Coevolutionary Development Paradigm," which could have provided an integrating framework for the whole book. Based on work by A. Terry Rambo of the East-West Center, it relates the evolution of the *ecosystem* with the evolution of the *social system*. If other authors had used that model as a base and built their chapters on its concepts and variables, the book might have been more useful. However, that would have been a rare and difficult achievement. Perhaps each reader can relate the various chapters to personal conceptual frameworks.

In a brief postscript, the editors offer this optimistic assessment: "Reports such as those collected in this volume offer much to the practitioner who seeks models of what works, and how; what doesn't work, and why. They offer something also to the planner, the researcher, the academic, the student--all of whom seek to identify, perhaps to formulate, paradigms to more effectively guide future efforts focused on the sustainable development of natural resources."

In my opinion, the book is strong on telling *how* some things were done, or some problems were encountered, but it fails to address the issues of *why* those things were done or *why* that problem exists. It makes many practical and useful suggestions, but none of these are especially new to scholars or practitioners. Recent literature is full of similar anecdotes and descriptions.--*George H. Axinn, Professor, Department of Resource Development, Michigan State University, East Lansing, MI.*

U.S. Agriculture in a Global Setting: An Agenda for the Future. 1988. M. Ann Tutwiler, Editor. National Center for Food and Agricultural Policy Annual Policy Review, 1987/88. Resources for the Future, Washington, DC. 234 pp. $20.00, paper.

This volume, the third in a series, is an effort by the staff of the National Center for Food and Agricultural Policy to cover the major policy issues affecting U.S. agriculture, both domestically and internationally. Besides its introductory and concluding overviews, it consists of 12 chapters grouped under four headings: the foundation of U.S. agricultural policy; the international setting; the domestic setting; and the environmental and technological setting. Its major themes include U.S. agriculture's growing economic interdependence with the rest of the world; changing attitudes of taxpayers and food consumers towards public support of agriculture and towards nutrition and food safety issues; and the relationship between agriculture and our soil and water resource base and global climate.

The book addresses an important need in that it covers agricultural policy in its broad features in a way suitable for non-specialists. I think it would be most useful for someone already involved in an agriculturally related field -- not the lay public -- who wishes to become more familiar with the larger policy environment in which agriculture functions. Generally speaking, the chapters are informative and worthwile. Most avoid overtly partisan biases, although the authors clearly have their own points of view.

Unfortunately, several problems

keep the book from fully achieving its admirable goal. Some of the chapters seem at too low a level even for the non-specialist. In particular, the discussion of consumers' demands consists largely of obvious generalities, presented with little insight. Second, although the editor and authors have substantially achieved their goal of creating an integrated volume, inconsistencies remain in both style and content. Some chapters take a long-range perspective and present considerable background material, while others emphasize very current developments, as would be more appropriate for a magazine rather than a book.

Finally, many corners have been cut. There is no index, and there are several inconsistencies between the source as cited in the text versus how it appears in the reference list. Also, page numbers are sometimes omitted for journal articles. Most seriously, there are numerous factual errors. For example, on p. 15 it is stated that mechanization had replaced horses by 1900. In fact, mechanization before 1900 almost exclusively involved implements, not the power source; serious replacement of horses began only after World War I and took several decades. On p. 53, economic conditions during the 1980s are described as "deflation" when what actually happened was a reduction in the rate of inflation, which is not at all the same. The chapter on rural demographics consistently treats the distinction "metro/nonmetro" as interchangeable with "rural/urban," thereby missing an important point. Three figures for total farm income for various years in the 1930s are all given in millions of dollars, when they should have been in billions (p. 20).

These and several other errors like them distress me because they occur in a potentially valuable book that comes close to fulfilling its worthy purpose. Unfortunately, they cast a shadow over the entire work; I would not use any facts from this book without first checking the primary source, a task that the reader should not be required to undertake. Were it not for this important flaw, I would be able to recommend the book as providing a good treatment of a wide range of significant policy issues. -- *William Lockeretz, Research Associate Professor, School of Nutrition, Tufts University, Medford, MA.*

UPCOMING EVENTS

December 2-5. Midwest Fish and Wildlife Conference, in Minneapolis, Minnesota. A day-long session will address "Changing Farm Practices: Sustainable Benefits for Fish and Wildlife?" Papers and poster sessions are invited. For information on the special session, contact Ann Robinson, Izaak Walton League, 801 Commerce Drive, Decorah, IA 52101, (319) 382-2947. For information on the general conference, contact Blair Joselyn, Wildlife Research, Box 7, Minnesota Department of Natural Resources, 500 Lafayette Road, St. Paul, MN 55155-4007, (612) 296-3344.

December 4-5. Farming for the Future is a training session at Atlantic City, New Jersey, on organic and sustainable agriculture for Cooperative Extension and other agriculture professionals. Contact Jean Hornyak, Rutgers Cooperative Extension of Mercer County, 930 Spruce Street, Trenton, NJ 08648.

February 15-16, 1991. National Conference on Organic/Sustainable Agriculture Policies in Washington, DC. Contact Center for Science in the Public Interest, 1875 Connecticut Avenue, NW, Suite 300, Washington, DC 20009-5728, (202) 265-4954.

March 2-3, 1991. Annual Conference of the Ohio Ecological Food and Farm Association at the Agricultural Technical Institute of The Ohio State University, Wooster. Contact OEFFA at 65 Plymouth Street, Plymouth, OH 44865.

March 5, 1991. Understanding the True Cost of Food: Considerations for a Sustainable Food System is the theme of a one-day symposium in Washington, DC, sponsored by the Institute for Alternative Agriculture. Contact the Institute at 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770.

March 5-6, 1991. Sustainable Agriculture Conference, sponsored by the Wisconsin Department of Agriculture's Sustainable Agriculture Program and several co-sponsors. Workshops, informational sessions, and institutional updates. Contact Joanne Eveland, Sustainable Agriculture Program, P.O. Box 7883, Madison, WI 53707, (608) 267-3318.

March 11-14, 1991. International Conference on Agriculture and the Environment, sponsored by Ohio State University, in Columbus, Ohio. Paper and poster proposals are requested. For information, contact Dr. Clive A. Edwards, Department of Entomology, Ohio State University, 1735 Neil Avenue, Columbus, OH 43210.

Nebraska proposes "Sustainable Future" book series

The University of Nebraska Press is accepting book proposals for a series of books on "Our Sustainable Future," designed to explore resource efficiency and sustainability of agriculture and other industries. The series is designed to bring together ideas and topics from biology, history, literature, political science, ecology, and the arts. For more information, contact Charles Francis, Department of Agronomy, 279 Plant Sciences Building, University of Nebraska, Lincoln, NE 68583-0910.

Neill Schaller joins IAA as Associate Director; Receives Professional of the Year Award

Neill Schaller, formerly Program Director of the Low-Input Sustainable Agriculture (LISA) research and education program at the USDA, was named Associate Director of the Institute for Alternative Agriculture in September, 1990. "Neill's extensive background in alternative agriculture issues from policy, research, and educational perspectives will be enormously helpful in moving the Institute's expanding agenda forward," said IAA Executive Director Dr. Garth Youngberg. Prior to his administration of the LISA program, Dr. Schaller had been Assistant Director of Natural Resource Economics Research at the USDA Economic Research Service, Special Assistant to the Secretary for Consumer Affairs, and Administrator of the Extension Service. Schaller holds an A.B. degree in sociology from Princeton University and a Ph.D. in agricultural economics from the University of California-Berkeley.

In September, Dr. Schaller was notified that he had been selected to receive the Professional of the Year Award from the Organization of Professional Employees of the Department of Agriculture (OPEDA). This recognition stemmed from "the quality of his work and interest in agriculture," according to Otis Thompson, Executive Director of the 7,500-member organization. The award was presented during a three-day annual OPEDA meeting in October. "This award is our organization's highest honor," said Mr. Thompson.

LETTERS TO THE EDITOR INVITED

The AJAA welcomes letters, short or long, commenting on articles in this journal or sharing ideas likely to be of interest to other AJAA readers. Since our space is limited, we do reserve the right not to publish all letters or, at times, to publish only excerpts from them. To take part in this exchange of ideas, write to: Editor, AJAA, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770.

Ward Sinclair receives top food columnist award

IAA Board Member, Ward Sinclair, has been named top food columnist by the Newspaper Food Editors and Writers Association. Sinclair, who operates an organic vegetable and fruit farm near Dott, PA, contributes a monthly column to the *Washington Post* called "Truck Patch." The witty and informative column focuses on the difficulties and rewards of growing and marketing a wide array of fresh produce on some 15 cultivated acres. Sinclair was the agricultural reporter at the *Post* for nearly 7 years. He and his partner, Cass Peterson, took up farming on a full-time basis in 1988.

Johnson, Adams, Vidaver named to IAA Board

At their annual mid-year meeting on September 8 in Moscow, Idaho, IAA's Board of Directors elected three new members. Paul W. Johnson operates a dairy, sheep, and Christmas tree farm near Decorah, Iowa. Since 1984 he has served in the Iowa General Assembly where he was major author of the historic 1987 Iowa Groundwater Protection Act. Dr. Eugene W. Adams is Professor Emeritus, International Education and Extension, Tuskegee University. Specializing in veterinary education and research, Dr. Adams has for two decades provided leadership in international agricultural development in a number of African and Caribbean countries. Dr. Anne K. Vidaver is Head of the Department of Plant Pathology at the University of Nebraska. Her research and administrative interests include participation and leadership in interdisciplinary science, especially as related to managed ecosystems. The three will be formally seated on the Board at its annual meeting in March, 1991.

Mr. Jay Harris of Berwyn, Pennsylvania, is slated to complete his Board tenure in March, 1991. He was presented with a certificate of appreciation for his long and active service. Mr. Harris served on the Executive Committee for three years.

In addition to its regular business, the Board, along with the College of Agriculture and Home Economics at Washington State University, co-hosted a Friday evening reception at the Lewis Alumni Centre on the University's campus.

Highest conservation honor goes to Norm Berg

Norm Berg, who serves on the IAA's President's Council, last summer received the Hugh Hammond Bennett Award from the Soil and Water Conservation Society. It is the Society's most prestigious award, given to no more than one individual annually in recognition of distinguished service and international accomplishments in land and water conservation.

Berg, who serves part time as the Society's representative in Washington, DC, was recognized for his achievements in furthering a conservation ethic on both national and international levels for nearly 50 years. Berg's long and distinguished career included several years as Chief of USDA's Soil Conservation Service.

OPINION—continued from page 50

University of California researcher summarized research on the topic as follows:

> As farm size and absentee ownership increase, we have found depressed median family incomes, high levels of poverty, low education levels, social and economic inequality between ethnic groups, etc., associated with land and capital concentration in agriculture....Communities that are surrounded by farms that are larger than can be operated by a family unit have a bi-modal income distribution with a few wealthy elites, a majority of poor laborers, and virtually no middle class. The absence of a middle class at the community level has a serious negative effect on both the quality and quantity of social and commercial services, public education, local governments, etc. (MacCannell, 1983).

Likewise, Nebraska research reveals a direct correlation between concentration in agriculture and the social and economic decline of agriculturally based communities (Swanson, 1980).

The challenge to sustainable agriculture is to develop farming systems that address these social concerns, as they address environmental quality. Just as sustainable agriculture seeks to address problems of production holistically, we will be most effective if we address social and environmental goals simultaneously and holistically. A piecemeal approach may result in social and environmental initiatives that are at odds with each other. For example, commodity programs aimed at supporting farm income now undermine sustainable production systems. Such conflict is not inevitable, but rather is a result of seeking piecemeal solutions to intertwined problems. We can choose to develop and shape sustainable systems to enhance family farming and the rural environment, or we can ignore the former and blindly develop systems that put the two in opposition.

Following are some approaches for incorporating social sustainability in sustainable farming systems by consciously shaping them to provide increased opportunities for moderate-sized owner-operated farms:

--Reduce purchases of both chemical and nonchemical inputs from off the farm, rather than replacing petrochemicals with environmentally benign alternative products. Reducing input purchases reduces capital barriers to young people getting started in farming. It keeps a larger share of the farm dollar on the farm to provide income to farm operators. Finally, it reduces the advantage that large farms gain over moderate-sized farms through volume discounts, and thereby helps level the playing field. Volume discounts provide a significant competitive advantage to large farms (Knutson, 1987).

--Increase opportunities to apply and earn a return on *skilled* labor and intensive management in the field and barn. Skilled and highly motivated labor and hands-on management are the principal strengths and competitive advantages of family farmers. Strategies are needed for using them to reduce input costs and capital requirements and increase returns. However, systems dependent on large amounts of *unskilled* labor beyond that which can be provided by farm families (for example, extensive hand weeding of field crops) may instead lend themselves to a class-structured agriculture with armies of poorly paid farm workers. Likewise, production systems that require high degrees of organizational management easily separable from provision of labor and performed in the office, such as acquiring assets, managing investments, and risk management, also lend themselves well to a class-structured agriculture.

--Develop farming systems that can be applied at least as economically on moderate-sized farms as on large operations. Typically, farming systems that require large fixed investments of capital, such as total confinement livestock systems, are most economical on a large scale because of the need to spread high fixed costs over many units of production. However, moderate investment systems can often be as profitable on a moderate scale.

The environment and family farming need not be placed in competition. Farming systems can be designed to support farm opportunities, equity, and rural community vitality as they sustain our resource endowment. However, that will not happen unless we make it happen. We must consciously set research priorities and design farming systems that advance the public interest in its social as well as its environmental aspects. In short, sustainable agriculture must take an holistic approach to issues of social justice and environment, just as it takes an holistic approach to problems on the farm.

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Editor's note for future AJAA authors

We would like to call your attention to an addition to the "Guide for Authors" on the inside back cover of this issue, in which we recommend the best kinds of sources to cite. Where there is a choice, we ask that you give preference to readily available materials (books, journal articles, or documents from institutions with well-established publication programs, such as experiment station bulletins). Less desirable is the so-called "fugitive literature," such as texts of conference presentations, internal working papers, progress reports, and other unpublished or informally published material.

The reason for this recommendation is that a citation not only gives credit for other people's work, but should also allow the reader to pursue the matter in more depth. The latter function is fulfilled only if the material you cite is reasonably available, either at a library or from the source. Remember, too, that "available" means not just immediately, but for as many years into the future as you would like your article to be read. It is frustrating if the reader is not able to get hold of a key reference; by citing available sources, you will greatly enhance the value of your article.

Guide for authors

The American Journal of Alternative Agriculture (AJAA) publishes original research on biological, physical, or social science aspects of alternative agriculture. We particularly welcome multi-disciplinary studies, but papers from a specific discipline also are invited. However, since AJAA readership is much broader than for a single-discipline journal, highly specialized terminology should be explained or avoided. The significance of a statement, or the reasoning behind a conclusion, may have to be spelled out more than in a more specialized journal. See Vol. 5, No. 1, pp 2 & 3, for an explanation of the various categories of articles.

Units

Research papers should use the International (SI, or metric) system throughout. Occasional use of common unit equivalents in parentheses is permitted, mainly for relatively exotic SI units.

Title page

The title page should give the following information (all flush left): 1) title of the paper; 2) names of authors; 3) affiliation and office address of authors, and 4) acknowledgements, if any. See examples in this issue of AJAA.

Abstract

The abstract should be 200 to 400 words suitable for readers from a broad range of disciplines. It should avoid highly-specialized terminology that might be appropriate for a single discipline journal. Take particular care that the significance of the work is made clear, even to readers from a different field.

Key words

Provide subject matter key words suitable for use in scientific indexing.

Reference list

When citing material that has been covered in more than one format, such as the typescript of a conference presentation and a journal article, preference should be given to the version that is most readily available, and that is likely to remain so. Generally this means standard publication channels, such as books, journals, and regular government report series. Unpublished or informally-published material should be cited only when no alternative form exists.

References should be listed in alphabetical order by author's name, and by year for a particular author (with letters after the year if needed). If a sole author is also the lead author of papers with multiple authors, use the following order: single author (by year); two authors (alphabetically by second author's name); three or more authors (by year). Repeat the author's name for each reference. Use initials only for first and middle names. Give the names of all authors in the reference; never use "et al."

Use full names of journals, institutions, conferences, etc., except for extremely familiar abbreviations like "Dept." Remember that an abbreviation familiar to you may not be familiar to readers outside your field. If in doubt, write it out.

The reference list uses no quotation marks, italics, boldface, or underlining. Only the names of books and periodicals are in initial capitals. Names of papers, book chapters, pamphlets, and bulletins are not capitalized. Page numbers are written out in full (e.g., 1108-1123, not 1108-23). The volume is given if page numbers begin at 1 for each issue.

Citing references

Cite references in the text by last name and year, with chapter or page numbers if the reference is a book or lengthy report. For two authors, give both names. Do not use "et al." unless there are at least three authors.

Footnotes

AJAA does not use bibliographic or substantive footnotes. All bibliographic references should be at the end of the text. Instead of substantive footnotes, include the material in the main text or consider eliminating it.

Manuscript preparation

The entire manuscript, including abstract and references, should be typed on one side of standard-size paper, double spaced, with margins of at least one inch all around. Starting with the title page, label all pages in the upper righthand corner with the lead author's last name and the page number. Do not use hyphens unless the hyphen is part of the word.

Follow the section headings style used in this AJAA issue. All headings are flush left, with no underlining or italics.

Tables should fit on one page, be numbered consecutively with Arabic numerals, and be on a separate sheet. Leave extra space to separate columns. Every figure and table should be mentioned at least once in the text.

Submission of manuscripts

Submit four high-quality copies to Editor, American Journal of Alternative Agriculture, Suite 117, 9200 Edmonston Road, Greenbelt, MD 20770. The cover letter should state that the manuscript is an original contribution that has not been published elsewhere in substantially the same form; that it is not currently under consideration elsewhere, and that permission has been obtained for any copyrighted material used.

How you can help support the scientific and educational needs of a sustainable agricultural system

A growing number of Americans have become concerned about the long-term sustainability of our food production system. Farmers and agricultural scientists are among those raising questions about the growing dependence of modern farming on nonrenewable resources, the depletion of our resource base through soil erosion, and heavy reliance on chemical fertilizers and pesticides. Continued heavy reliance on farm chemicals is questioned because they have become an expensive production input. Their widespread use also raises questions about human and animal health, food quality and safety, environmental quality, and the continued demise of the family farm.

Low-input alternative farming methods address these economic and environmental challenges. Alternative production systems point the way toward more profits, more individual choice, and long-term sustainability for our food system. More must be done to develop effective ways to make sure research, education, and information sources are readily available to farmers who want to adopt these techniques.

The Institute for Alternative Agriculture needs your help in meeting this challenge. We are a nonprofit tax-exempt research and education organization set up in 1983 to encourage and facilitate the adoption of low cost, resource conserving, and environmentally sound farming methods. We work directly with government agencies, colleges and universities, producer groups, and other institutions that provide research, education and information services to farmers.

The Institute also provides these services:

- *A resource to lawmakers and others who influence agricultural research, education, and information policy*
- *A voice for alternative agriculture in Washington*
- *A sponsor of research and education outreach programs*
- *A national clearinghouse for information on alternative agriculture*
- *A publisher of reliable scientific information on agricultural sustainability*

If you're interested in helping us, please contact our office at 9200 Edmonston Road, Greenbelt, MD 20770. The phone number is (301) 441-8777.

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